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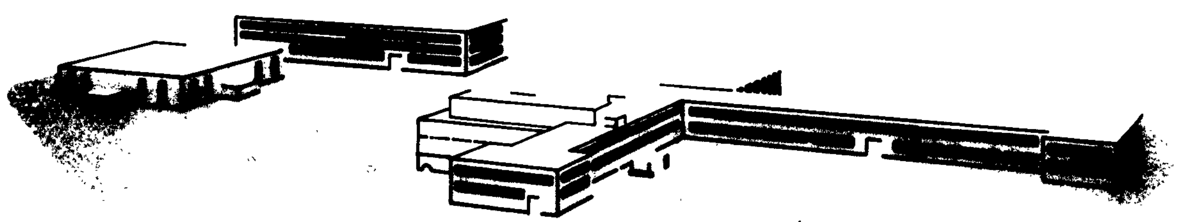
TRENDS IN THE INFORMATION SCIENCES RELATIVE TO NAVAL INTELLIGENCE NEEDS



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TRENDS IN THE INFORMATION SCIENCES RELATIVE TO NAVAL INTELLIGENCE NEEDS

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ABSTRACT

This report defines the information sciences by listing the interdisciplinary scientific and technological areas involved. It discusses state-of-the-art trends and research activities in a number of areas of the information sciences which have direct application to intelligence, information, and command and control systems. It correlates important state-of-the-art trends and research areas of broad scope with system design and with present and future system problems and needs. The correlation is in terms of the demands and possible threats of the coming two decades.

"It takes all the running
you can do just to stay
in one place. If you want
to move ahead you must run
faster than that."

(Lewis Carrol-Through
the Looking Glass.)

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1.0 INTRODUCTION

Research and Future System needs - The 'Systems' concept in integrating research efforts - General system theory - Modern heuristics - The 'Poor Boy' concept relating efficiency, economy and functional solution of system problems - Report focus on state-of-the-art and research trends and system impact in a two decade span.

This report represents an introductory study in state-of-the-art trends in the information sciences and technologies as they apply to intelligence, information handling, and military command and control systems. Interdisciplinary research and development trends, characteristic of the information sciences, are related to future advanced system needs and problems. The report covers the following:

1. Lists currently active areas of research and technology having applicability to advanced system problems.
2. Discusses state of the art in several areas pertinent to system design, functions, problems and needs of the evolving system of the coming two decades.
3. Lists typical, advanced system problems and needs in terms of the demands and possible threats of the coming two decades.
4. Surveys and lists general research and study areas which have specific applicability to future, advanced system requirements as indicated in (3).
5. Lists and evaluates interdisciplinary research in terms of present activities, effort levels and future outlook. Weight is given to those research areas whose scope and potentialities are sufficient to support research planning with a high probability of solution, not of single technological problems, but of ranges of complex system problems.

As defined in this report, the information sciences cut across almost every realm of scientific endeavor including physics, psychology, biology, chemistry and the broader classifications of system theory, information theory, cybernetics, and communication. Examples include linguistics, semantics, sensory mechanisms, memory, speech analysis, learning, self organization, pattern recognition, control theory, molecular electronics, etc.

One of the requirements of a state-of-the-art study in areas of pertinence to a specific system or systems is a picture of the general scope of the subjects considered as relevant. Where intelligence and information areas are concerned, the range of related effort activities is so great that a categorized "list" is the best approach to a definition of scope. Figure 1 illustrates the wide range covered by these seemingly diverse areas of research and technology. In this report they are examined within the integrating framework of the "system"; specifically of intelligence, information, and command control systems and in the time perspective of system functional capabilities in the 1970 to 1980 era.

The two past decades have witnessed the emergence of "system" as a key concept in research. This concept represents the strong and continually growing tendency in contemporary science to no longer isolate phenomena in narrow categories and contexts. The trend is to integrate scientific knowledge and research efforts within the larger framework of the "system" for study as an entity rather than a collection of independent unrelated efforts.

These trends have been and are being strongly influenced by "General System Theory" (von Bertalanffy L. 1962) which merges the many fields of the sciences within the concepts of "General System Theory" and underlines the importance of the basic similarities of all "systems" from complex biological systems through mechanistic, electronic, economic and social systems including information handling systems (See end of section 2.3).

Related to this merging is the trend to increasing emphasis and interest in the use of broader problem-solving methods. These methods, under the name of heuristics (search, discovery), are based upon our present and increasing knowledge of the methods and patterns of human problem solving, which in approaching complex problems take on the characteristics of inductive and controlled inferential processes. Much remains to be done in this area, but practical and fruitful applications have been and are being made.

RESEARCH AND TECHNOLOGICAL AREAS OF DIRECT PERTINENCE TO INTELLIGENCE AND INFORMATION SYSTEMS

SYSTEMS – SYSTEM THEORY

- MANAGEMENT SYSTEMS
- COMMAND AND CONTROL SYSTEMS
- INTELLIGENCE-INFORMATION SYSTEMS
- ROLE OF INFORMATION SCIENCES
- GENERAL SYSTEM THEORY
- SYSTEM EVALUATION METHODS
- PATTERNS OF SYSTEM ORGANIZATION
- OPTICS-OPTOELECTRONICS IN SYSTEM DESIGN
- SYSTEM RELIABILITY-REDUNDANCY-MAJORITY LOGIC
- NON-DETERMINISTIC SYSTEM CHARACTERISTICS
- SYSTEM INVULNERABILITY-SELF REPAIR
- MOLECULAR ELECTRONICS AND SYSTEM DESIGN

ADVANCED INFORMATION SCIENCES

- CLASSIFICATION THEORY
- HYP. FORMULATION BY COMPUTERS
- PERCEPTRONS
- ARTIFICIAL INTELLIGENCE
- SELF ORGANIZATION
- ADAPTIVE SYSTEM CONCEPTS
- LEARNING CONTROL SYSTEMS
- HEURISTIC CONCEPTS IN PROGRAMMING
- LEARNING MECHANISMS
- RECENT DEV. IN LEARNING MACHINES
- MATERIALS RESEARCH-ORGANIC-INORGANIC
- BRAIN MODELS-BIOLOGICAL ANALOGIES IN DESIGN
- DISTRIBUTED MEMORY (ASSOCIATIVE)
- MAN-MACHINE RELATIONSHIPS
- SENSORY INFO. AND BIOL. MODELS
- ASSOCIATIVE MEMORY CONCEPTS
- NEURAL NETS-SPEECH ANALYSIS
- AUTOMATA AND THOUGHT PROCESSES
- PATTERN RECOGNITION
- MACHINE SIMULATION AS A RESEARCH TOOL

COMPUTERS AND INFORMATION SYSTEMS

- PROBLEMS OF MULTILEVEL MEMORY SYSTEMS
- THREE DIMENSIONAL CORE MEMORIES
- SINGLE LEVEL MEMORY UNIFICATION CONCEPTS
- FIXED-PLUS VARIABLE COMPUTER SYSTEMS
- REAL TIME MULTIPROGRAMMING-THE MAC CONCEPT
- DIG. DATA COMMUNICATION
- PROGRAMMING THEORY-TECHNIQUES
- PROGRAMMING LANGUAGES-HEURISTICS
- ANALOG-DIGITAL-HYBRID SYSTEMS
- PERIPHERAL EQUIPMENT-BOTTLENECKS
- MACHINE ORGANIZATION
- COMPUTER MACHINE SWITCHING IN COMMUNICATION SYSTEMS
- MATHEMATICS-UNSOLVABLE PROBLEMS-HEURISTICS
- ERROR DETECTION-CORRECTION-CONTROL
- MULTIPROGRAMMING
- TIME SHARING
- AUTO-PROGRAMMING
- COMPUTER PROBLEM AREAS
- AVALIABILITY-PERFORMANCE TABULATION
- COMPUTER SYSTEMS-VON NEUMAN VERSUS INFORMATION HANDLING MACHINES
- OPTICAL COMPUTERS-OPTICAL COMPUTER TECHNIQUES

MACHINE TRANSLATION

- GLOSSARY TRANSLATION METHODS
- SINGLE DISCIPLINE TEXT FORMULATION OF GLOSSARIES
- TABLE LOOKUP METHODS
- CYCLIC METHODS IN MACHINE CONDITIONING
- PROBLEMS OF TRANSLATION EVALUATION
- GENERATIVE GRAMMAR
- TRANSFORMATIONAL GRAMMAR
- MACHINE PARSING-LANGUAGE PAIRS
- MECHANICAL SYNTACTIC ANALYSIS
- INTERLINGUAL ELEMENTS IN SYNTAX
- MULTIPATH SYNTACTIC ANALYSIS (SOVIET)
- COMPARATIVE LANGUAGE MORPHOLOGY
- ALGORITHMS-LANGUAGE MODELS
- SEMANTICS PROBLEM AREA
- POLYSEMY-DOUBLE MEANING
- INTERMEDIATE LANGUAGES
- MATHEMATICAL LINGUISTICS

INFORMATION RETRIEVAL

- RESEARCH IN SEARCH STRATEGIES
- SELF ORGANIZING FILE CONCEPTS
- LANGUAGE MORPHOLOGY-ABSTRACTING/ INDEXING PRINCIPLES
- CONTROL TECHNIQUES
- ASSOCIATIVE STORAGE/RETRIEVAL METHODS
- MULTILEVEL, MULTIDIMENSIONAL RETRIEVAL
- CODE STRUCTURING
- SYNTACTICALLY RELATED DESCRIPTOR RETRIEVAL
- KEYWORD IN CONTEXT-SUBJECT HEADING CLASSIFICATION
- MECHANIZED SEMANTIC CLASSIFICATION TECHNIQUES
- LOGICO-LINGUISTIC BASIS OF RETRIEVAL SYSTEMS
- MACHINE ABSTRACTING-INDEXING
- NATURAL LANGUAGE QUERY-RESPONSE METHODS
- FACT CORRELATION FOR INTELLIGENCE ANALYSIS
- STATISTICAL ANALYSIS WORD FREQ. AND RETRIEVAL
- SYSTEMS
    - REFERENCE STORE
    - DATA STORE
    - MACHINE SEARCHABLE FILES
    - MICROFILM TAPE
    - MICROFICHE CARDS
    - APERTURE OPTICAL CARDS
- COORDINATE INDEXING SYSTEMS

TECHNOLOGICAL DEVELOPMENTS

- INTEGRATED CIRCUITRY
- PIEZO-ELECTRIC ULTRASONIC AMPLIFIERS
- PHOTO-PIEZO-ELECTRIC DEVICES
- MOLECULAR ELECTRONICS
- MODULAR TECHNIQUES
- PLUGGABLE MEMORY MODELS
- DISTRIBUTED MEMORY TECHNIQUES
- BUILT-IN PERIPHERAL AND CONTROL PROCESSORS
- SEMICONDUCTOR INFRARED BEAM GENERATOR
- THIN-FILM TECHNIQUES-DEVICES
- OPTICAL TECHNIQUES-OPTICAL COMPUTERS
- HOMOGENEOUS SEMICONDUCTORS DEVELOPMENT
- CRYOTRONS-SUPERCONDUCTIVITY-FIELD DEVICES
- PHOTO-FERRO-ELECTRIC EFFECTS-DEVICES
- CURRENT STEERING LOGIC
- SEMICONDUCTOR LASERS-TRIODE LASER
- FUNCTIONAL DEVICES
- OPTICAL (LIGHT BEAM) WIRING TECHNIQUES

FIG. 1 - SCOPE AND INTERDISCIPLINARY NATURE OF THE INFORMATION SCIENCES

The methods are developing as a result of the need for solutions in areas where the usual deductive, analytical methods are proving ineffective. Examples would include complex system problems where the number of variables and conditions is so great that ordinary methods, either manual or machine, become impractical or impossible. In the coming decade or two, these trends of approach using General Systems concepts and heuristic methods will undoubtedly play an important part in focusing wide ranges of research efforts on the solution of the complex problems inevitable in systems which fuse man and machine into an effective working team. A concerted and intensified effort is necessary to keep abreast of the rapidly evolving research and development trends.

A conceptual grasp of the research and development picture must be maintained in an organized and continuous manner. Progress in those research areas of promise and possible applicability to intelligence system problems must be monitored, supported, and expanded where necessary. In this way new technologies can be most rapidly developed. New capabilities can be added to military intelligence, information and command and control systems and future, presently unforeseen threats successfully met.

In any attempt to present a comprehensive "overview" of extremely wide ranges of research and development efforts and trends, limitations are imposed by the very abundance of the source material and the time required to collect, read, and digest it. These limitations confined the report to selected areas of the broad scope of state-of-the-art considerations and limited depth of detail in many parts. Future reports must be depended upon to expand scope and depth. Report material sources include: attendance at various U.S. symposiums (Mil-E-Con 7; Naval R&D Clinic; ONR Supported; IEEE; etc.): Proceedings of Various U.S. Symposiums; Proceedings of Foreign Symposiums (UNESCO, Paris; 4th London, IFIP, Munich, etc.): U.S. and Foreign Technical Journals: Government Documents (ASTIA, OTS., etc.) Research Surveys (National Science Foundation, National Bureau of Standards, etc.): Trade Journals and Papers and other important sources which include operational site visits, observations, and personal interviews with specialists in particular fields. Some of the visits have served to confirm to a degree, the philosophy expressed in a concept named "Poor Boy" generated within CNO. This concept expresses the philosophy that efficiency and economy are served effectively where the tendency to overcentralization and its concomitant over-automation is carefully checked. The real functional demands of the overall system down to fleet levels including the amphibious and ASW must be served by appropriate means. Here the phrase "appropriate means" signifies the use of automatic and semi-automatic processing methods where required and advantageous, and the use of advanced manual methods and simple devices where they serve effectively and economically. This concept may be treated more extensively in a future report. It was thought advisable to indicate its importance as background perspective to the advanced research areas and system problems which are emphasized here.

It should be kept in mind that the focus in this report is on evolving state-of-the-art technologies and on research and development trends which can be expected to have a significant impact on systems and future system problems within a two decade time span. It was originally planned to consider the period of 1963 to 1970. The nature of the research and technological information collected, however, made it uneconomical to retain such a restriction. Hence the focus of the study has been expanded to cover a two decade period.

2.0 SYSTEM DESIGN TRENDS-HEURISTICS-GENERAL SYSTEM THEORY-COMPLEX SYSTEM PROBLEMS

System design trends-Heuristics and complex system problems-Man/machine language wall-Unsolvable problems-Fantastic costs of the programming 'Babel' -General System Theory-Nondeterministic machines-Machine acceptance-Research climate-Augmentation of man's intelligence.

2.1 System Design Trends

A number of trends are discernible in system design considerations. They include the following: (1) Increasing emphasis on man as a system component, (2) Decision structure as a basic determinant in design, (3) The increasing importance of gaming and simulation, (4) Recognition of the importance of an increasing appeal to research in information sciences, (5) Adaptive, nondeterministic system characteristics, (6) Increased invulnerability, (7) Modern heuristics in problem solving, programming, man/machine intercommunication, (8) General System Theory and its integration of interdisciplinary sciences. References of direct interest to these eight areas include the following: Sargent K. N. 1963; Krendell E. 1963; Raben M. W. 1960; Singleton J. W. 1960; Stoller - Van Horn 1958; Sabeh R. 1961; Burrows J. H. 1963; Bolt, Beranek, Newman Inc. 1962; Licklider 1962; Licklider 1961; Davis R. 1963; Morganstern 1963; Wiener N. 1949; Schaeffer - Shapero 1961; Lee F. 1962; Davis R. 1963; Angel J. B. 1963; Porter E. H. 1962; Mathis - Sass - Wilcox 1963; Polya G. 1957; Polya G. 1954; Carter E. 1961; Carter E. 1962; von Bertalanffy L. 1962; von Bertalanffy 1956; Truitt T. D. 1964.

2.2 Heuristic Methods and Complex System Problems

One of the interesting and perhaps most significant of these trends is the decreasing emphasis upon purely analytical methods and the increasing emphasis and interest in broader and more flexible methods of solving complex system problems where purely deductive and analytical methods of conventional mathematics are proving impractical or impossible. New methods are emerging under the name of 'modern heuristics' which involve the use of (1) Inductive and inferential processes, (2) Analogy, (3) Isomorphic laws and relationships in diverse system types, and (4) Formulation of basic patterns in human problem solving.

Heuristic reasoning is reasoning not regarded as final, but provisional. In such problem areas, the provisional is needed before attaining the final, for modern heuristics aims at generality and at the examination of procedures which are independent of subject matter and have application to wide ranges and types of problems. In this sense, modern heuristics has common ground with General System Theory which spans wide ranges of interdisciplinary scientific knowledge within the integrating framework of the general system. Trends in modern system design cut directly across the area of heuristic problem approaches. This results from the fact that a design level is being approached where subsystem components and their speed and efficiency of operation no longer present a major problem. The critical problem areas have risen above the component level and are now at the "system" level. This means problems of system structure and organization and involvement with considerations of human judgment, decision processes, and man-machine communication interfaces and interrelationships. It is here that the need exists for new problem approaches and an increased appeal to the broader powers inherent in heuristics (Polya G. 1954), General System Theory (von Bertalanffy 1956-1962) and cybernetics (Ashby R. 1963).

Heuristic techniques are built upon human patterns and processes of learning, information processing, and problem solving approaches. In these areas we have barely begun to tap, through research, a field of knowledge which promises to pay richly. More basic information is needed on the role played by imagery and language in problem solving and on the invariants in mental patterns involved in solving wide varieties of problems including both numerical and non-numerical problems. The computer is a machine. It must be programmed, told what to do, "trained" by men. Until we have a wider knowledge of our own mental processes in reaching problem solutions, the computers' limitations will be simply a projection of our own limitations of self-knowledge. There is a wide range of problems in both the numerical and nonnumerical categories, which are not now being processed. These are problems which are not well structured or precisely defined and for which no formal algorithms (solution patterns) exist. Decision problems involving many variables, complex man/machine system problems, machine language translation problems, myriad variable and combinatorial problems are examples. It is virtually impossible to program such problems with present formal programming techniques with their rigid inflexibilities. The statement of Marvin Minsky of MIT is of interest here. He states that a machine capable of augmenting human intelligence must be capable of coordinated search, pattern recognition, learning, planning and induction (Diebold Report 1962). It is interesting to note that in Polya's work on heuristics methods in problem solving, these five items are listed as patterned steps to be taken by the human problem solver in attacking any unsolved problem (Polya G. 1957).

The Programming language problem is another area in which heuristic methods can make significant contributions. Computer programming has become a "Babel" of many tongues. Fantastic expenses are involved in dealing with complex, esoteric programming techniques which constitute our only major means of man/machine intercommunication. This Babel of computer languages makes significant service wide or world wide computer intercommunication impractical or impossible. There are techniques evolving at the present time which may open new avenues of man/computer communication. These include the light pen/Cathode ray tube (Weisberg D.D. 1964), and computer produced moving pictures and animation (Knowlton K.C. 1964). In the light pen/CRT approach, computer communication is achieved by writing on the surface of a console CRT display unit with a light pen. Computer commands can be given, requests made, design sketches made and manipulated. The technique is being widely presented at present as a computer aided design tool. It also plays an important part in a Navy data handling system which will not be discussed in this report.

The man/machine 'wall' represented by rigid, formal, programming techniques and the interpositioning of specially trained programmers and operators between the real user and the machine is the critical obstacle in man/machine intercommunication and interrelationships.. It is a portentous factor in the lack of acceptance of the machine in many quarters as an aid in decision making and in general in the augmentation of human intelligence.

These two areas of man/machine problem solving and the man/machine language barriers represent critically important system needs. Intensified research in modern heuristics, man's problem solving patterns and methods, heuristic programming and machine intercommunication methods promise direct rewards in the solution of pivotal problems which have wide ramifications in intelligence and information processing areas (Simon H.A. 1964).

There has been some progress in application, particularly in heuristic programming of computers and in the solution of problems not accessible to formal analytical methods. Examples of these areas include management science, language manipulation, game theory, and study of processes in mathematical proof techniques. There are a few active research projects at the present time in theseareas, but considering the promise and potential, the effort is extremely small.

Heuristic programming has the potential of transforming a computer into a machine exhibiting many of the characteristics of human intelligence. It is highly probable that it can be developed into a vital aid in military decision making where the time constraints and the number of variables involved make machine aid a necessity. The basis of the power of heuristics lies in its inherent capability to reduce the tremendous work load that complex problems offer in terms of overwhelming numbers of conditions and variables and the volume of data to be assayed. The technique has the capability of rapidly reducing the vast "solution search space" in which the problem solution exists. Recent work in the field has shown that in areas of decision making, these methods can reduce the occurrence of fallacies and radically shorten decision time. (Gagliardi U. 1963).

One development which resulted from research in heuristic techniques is that of "List Processing" which evolved during the writing of heuristic programs to simulate cognitive processes. This technique reflects and affects heuristic methods and in practical use lends great flexibility to the writing of commands and data structures. It is a powerful tool in the manipulation of natural language, in modeling and in process simulation. List processing is a step toward associative memory and involves "linked storage" resulting in the capability to retrieve chains of associated materials without the limiting constraints of individual addresses for each stored item (Newell A. 1961).

There is evidence that patterns of heuristic methods may reflect themselves in the future in the actual physical organization and structure of computers. Although this cannot be documented at the present writing, it is known that Rand Corporation is interested in this aspect of heuristic techniques. Such a development would presumably add significantly to the power of heuristic machine techniques and further simplify man/machine intercommunication.

In sum, heuristic methods and techniques are in their infancy. They show a variety of significant potentialities and promise for military systems. Further research and study efforts are indicated and would seem to have a high probability of significant returns and a practical applicability to present and future system problems.

Research areas in modern heuristics of direct interest to the military and to intelligence and information handling systems would include: (1) the mathematics of induction, inference, principles of analogy, isomorphic relationships in diverse systems, (biological, mechanical, sociological, economic); (2) simulation of cognitive processes; (3) man/machine intercommunication and interrelationships (cyclic machine conditioning as in machine translation techniques); (4) the relationships between heuristic procedure patterns and possible new modes and patterns of computer internal structures; and (5) heuristic aids to decision making. (6) Investigation of rapid reduction of problem variables and parameters (reduction of solution space).

The volume of published materials and readily accessible information in the relatively new field of modern heuristics is somewhat limited. A collection of basic, interesting and directly related references will be found in the rear section of the report bibliography under the title of 'Descriptor Arranged References."

2.3 General Systems Theory

Of direct and significant interest to complex systems and system thinking, is the rise and rapid growth of 'General System Theory." The theoretical concepts involved are of particular interest to intelligence and information processing systems because of the theory's interdisciplinary nature. The theory has potential power as a research and design tool stemming from its merging and integration of widely diverse fields of scientific knowledge within the framework of General System Theory and its formulation of basic "principles" common to all systems from biological, mechanistic, electronic through economic, political and social systems.

Its concepts are directly in the line of thought expressing dissatisfaction with traditional system design methods and the need for a more advanced, sophisticated approach to the design of complex systems (Davis R.M. 1963).

Originating almost two decades ago as a paper delivered by L. von Bertalanffy at a University of Chicago seminar, growth of interest in its concepts has been continuous. The Yearbook publications of its eight year old "Society for General Systems Research" have become of interest to researchers in fields involving systems or system concepts. They are probably best known at present by researchers in the biological and social sciences.

The Theory has a high theoretical as well as practical interest to areas of system engineering and operations research because of the fact that it permits the system concept to be used as a fulcrum in dealing with heterogeneous entities of machines, men, inputs, flow, processing feedback and output. (Lorentz 1962). One of the most important objectives of the theory is the formulation of principles common to "systems" of any kind. This information is based upon the existence of isomorphic (identical) laws and principles in completely different fields of science. Despite the fact that the entities concerned may be radically different (atoms, molecules, animate or inanimate systems) basic laws and principles exist which apply to any system of a given type without respect to particular properties or particular elements involved. There also exist structural correspondences despite the radical differences in the nature of the component entities (von Bertalanffy 1950). Quantification is noted as only one of the functions contributing to scientific knowledge and an equally important role is given to the concept of "wholeness" or the perception of "gestalten". These facts are at the root of the increasing use of analogy, particularly biological analogies in research and design bearing upon systems. Articles and papers of an extremely interesting nature and of pointed significance to advanced thinking in general system theory are to be found in the Yearbooks of the Society For General System Research.* Recently (1964) elected president of the Society is W. Ross Ashby (U. Ill.) (General Systems-Vol VIII-1963). A collection of references on General System Theory is to be found in the descriptor arranged references in the rear section of this report's bibliography. Of note in practical application areas is the excellent text on a methodology for system engineering which reportedly has been directly influenced by the principles of General System Theory. (Hall A.D. 1962).

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3.0 ADAPTIVE SYSTEMS-MACHINE ACCEPTANCE-SOVIET ATTITUDES ON ARTIFICIAL INTELLIGENCE

Environmentally adaptive systems. Reliability-Invulnerability-Design considerations-Biological system analogies-Cybernetics-Simulation-Machine acceptance-Research climate-Soviet attitudes on machine intelligence-Status of artificial intelligence in the Soviet Union.

3.1 Adaptive, nondeterministic systems.

One of the considerations involving future systems and future system design is the concept of the adaptive, nondeterministic system as contrasted with the fixed response, deterministic system. Deterministic systems are those which react to environments in a fixed, specified manner. Output states are determined precisely by the inputs and both outputs and inputs are quantized quantities or events. An example is the conventional computer. Such systems, where used by the military, have critical weaknesses, the most serious of which is the lack of a capability to react to unexpected, unpredictable environmental changes. Thus the fixed response system is highly vulnerable. Partial damage puts it out of commission. Malfunction of subsystems or of individual components, or mishandling by personnel may render it ineffective to perform its mission.

In contrast to this, the adaptive self-organizing or nondeterministic system has the capability of responding effectively to unforeseen and perhaps hostile environmental changes. It is characterized by a high invulnerability involving self-repair capabilities and self-healing circuits (Computer Design 1964). Its responses to changes in the environment and/or operational situation are such that the system is able to continue to accomplish its major functions in the face of damage, component malfunctioning, changes in input data flow or even partial destruction.

Actual components and system organizations with these "designed in" characteristics exist and are experimentally operative within constraint limitations which are being progressively eliminated. There is a considerable amount of work being done in the area of adaptive networks and in self-repair and self-healing circuitry. Macro and microelectric systems will make increasing use of these developments (Angel J. B. 1963, von Neumann J. 1956, Widrow-Hoff 1960, Hoff M.E., Jr. 1962, Andrew A. M. 1963, Widrow B. 1963).

Some interesting thinking along these lines is to be found in a paper entitled "Meta Systems and the Deterministic Approach" presented at the Fourth National Symposium on Human Factors in Washington, D.C. May 1963 (Davis Ruth M. 1963). A Meta-System, in the terminology of the paper, is a more specialized, highly organized form of an original system. It manifests characteristics of adaptivity to environment and self-organization which lend it a high degree of reliability and invulnerability. Quoting the British neurologist Lord Adrian and using the illustrative analogy of mapping the physiological characteristics of the human body onto the brain, the paper presents a number of considerations for system designers which include the following. (1) The capability of the control center to temporarily suppress reception and/or processing of data on channels carrying information of secondary importance and to handle with full system efficiency only those channels carrying information of critical importance to the demands of the particular situation. (2) Incompatibility of a fixed, hierarchical, ordering of the information in a system with flexible, responsive organization. (3) There must be a capability to effectively order and respond to rapidly changing information patterns resulting from changing external environment or from changing demands within the system itself. (4) The information pattern within a system will not normally reflect the physical characteristics of the system's physical structures. The internal organization of complex systems may reflect physical system structure in a manner analogous to that exemplified by biological systems (man for example). In man the relatively enormous area occupied by the mapping on the brain of a sensor organ (eye for example) contrasts radically with the minute area occupied by the mapped area of arms or legs.

The paper is typical of trends in thinking at higher levels of system theory and design. Design trends are moving away from sequential blocked diagrams of specified outputs for given specified inputs. They are moving rapidly toward the environmental adapting, self-organizing system concepts; increased appeal to biological analogies (bionics); applications of wide ranges of the interdisciplinary sciences; and heavy emphasis on the complex problems of man/machine intercommunication and inter-relationships. Significant support in the approach and solution of the complex problems involved in man/machine problems will be given by General Systems Theory, heuristics, and cybernetics. Here cybernetics is defined as a comparative study of the control system formed by the human nervous system and brain and artificial, mechanico-electrical communication and control systems such as computers, information processing systems, machines which might augment human intelligence (Weiner N. 1948-1961) (Ashby R. 1963). The paper mentioned above (Davis R. 1963) suggests that knowledge of the need for modern, advanced design approaches should be widely promulgated and that such an approach is beyond neither the state of the art in hardware nor in design procedures. Trends and developments in the state of the arts covered in this report confirm this position. Recent theoretical studies in nondeterministic, adaptive systems have been incorporated in a computer simulation study which emphasizes the concept of a "learning" control system. The system combines adaptive system characteristics, and a "learning" capability, with digital memory and logic circuitry as requirements for satisfactory nondeterministic operation under changing environmental conditions (Hill-McMurty-Fu-1964). There is a growing maturity and sophistication in areas such as neural net concepts, cognitive systems simulation, research in adaptive systems and in self-organizing system concepts including self-repair and self-healing circuits. Progress in applications is in evidence in machine pattern discrimination, auto-translation, weather analyses and prediction, flight guidance and control and machine generalization through heuristic programming. The neural net approach to learning machines seems to be predominant and its perception devices show great promise (Overton R. K. 1963). Design interests could well take a preparatory and bold look at the coming two decade's feasibilities and possibilities.

3.2 Machine Acceptance

As the capabilities of machines are improved and their use grows more widespread, there is evidence of some resistance to the concept of the so-called "intelligent" machine. One form of this is the reluctance at some levels to extend a satisfactorily broad acceptance to the advanced machine. The resistance, though understandable, is unfortunate, being based upon questionable definitions of intelligence whose nature, characteristics, and capabilities have never and probably never will be entirely fathomed, defined, exhausted, or duplicated. It is felt in some circles that such resistance could affect the research climate with possible adverse effects on research in machine or so-called artificial intelligence. Development and assimilation of future advanced machine capabilities into complex systems could be affected (Armer P. 1963), (MacGowan 1960). The important consideration is the maintenance of tolerance on all sides of the question and to permit advances and developments to prove themselves.

Discussion for and against the machine has a literary history from the time of the creation of the "difference engine" calculator of Charles Babbage in the 1800's (Bowden 1953) through Samuel Butler's "machinist-antimachinist" civil war in "Erewhon" (Butler S. 1865 and 1933), to the modern discussions beginning with the unfortunate "Giant Brain" blurbs of the popular press of the 1940's. Important and interesting modern writings on the subject include A. M. Turing's paper on "Computer Machinery Intelligence" (Turing A. 1950); (Bowden 1950); (McGowan 1960); (Samuel 1960); and (Taube 1961). Interesting answers to Taube's strongly negative attitudes on machine and artificial intelligence are given in the reviews of the Taube book (Taube 1961), particularly the one by Richard Laing and also the one by Walter R. Reitman-(Reitman W. R. 1962) - (Laing 1962).

Wide acceptance of the advanced machine may take a considerable period of time. Machines will have to prove themselves in terms of their flexibility and capability particularly in areas of nonnumerical problem solving and as critically important aids in decision making at all levels. Training and familiarity in their use, breakdown of the communication barrier between the actual user and the machine and a more direct man/machine interchange and interrelationship will be steps in the development of knowledge and trust in the reliability of machine aids. (Selfridge O. 1964), (Carter E. 1964).

It is interesting to note that the first automatic data processing orientation seminar for general and flag officers at the U.S. Military Academy (West Point) was held recently (EDP 1963). Orientation was designed to provide insight into capabilities and limitations with emphasis placed on their growing and critical significance to command and control systems.

3.3 Soviet Attitudes on Machine Intelligence

Based on the visits and reports of scientists, knowledgable and capable in the fields of the information sciences, Soviet attitudes on advanced machines very closely parallel those of our own. In the USSR, artificial intelligence is classed as a research activity under cybernetics (Wiener N. 1948). It is recognized as an area involving both men and machines, requiring therefore a heavy interdisciplinary approach involving biology, chemistry, physics, linguistics, psychology, physiology, mathematics, engineering, automatic computing and so on. Soviet research activities related to artificial intelligence center mainly in (1) physiology, (2) psychology, (3) computing devices and (4) mathematics.

In physiological areas research is sophisticated and competent. Evidence indicates that one of the most active areas is neuro-physiology which is reported as creative and progressive with interest centering on structure and neural control activities. Laboratories visited were modern and well equipped. An article by D. A. Biriukev in the highly respected 'Sechenov Physiological Journal' of the USSR indicates long term plans for intensified research in the physio-chemical principles of neural activity (Freeman 1960), (Armer P. 1963). Much of the work is under security classification.

In psychological areas an upsurge of activity has been taking place in the past decade following the Stalinist downgrading of this science. Reportedly, psychologists working with physiologists are directing their research work toward human behavior and its source mechanisms with a view to incorporation of useful patterns into machines.

In the field of computing devices the Soviets are widely reported to be somewhat behind the U.S. First hand observation by Paul Armer during two weeks of visits to Soviet computer installations confirms numerous other reports on this (Armer P. 1963, p. 401). They are somewhat behind in terms of the number of computers in construction and in terms of input and output equipment. However, the Soviet use of computing machines is different in character than our own. The probability is that computer use is concentrated on scientific, technological, simulation and research problems. There is little if any use in areas such as the utilities (airline, electric power,) social security, subscriptions and gas station services. Although the Russians started work on computers later than we did (Wiener N. 1964) they have narrowed the gap significantly and there is nothing basically lacking in their state of the art. The quantity of machines is of less importance than the working assignments given to those available. There is no reason to believe that their research in areas of machine and artificial intelligence is in any serious way, constrained by the computer facilities available (Klauss 1960), (Armer P. 1963), (Ware 1960), (Feigenbaum 1961).

In mathematics, the Russians have had a top reputation for several decades. Past delegations of scientists to the USSR have been impressed with the number of top mathematicians working in computer and related fields. This coupled with reports that the Russians give considerable weight to simulation and modeling of human mental processes and activities and of the brain itself suggests that a considerable amount of mathematical talent may be engaged in these areas (Carr et al 1959) (Armer P 1963). In general there is considerable evidence that the Soviets are actively pursuing the concept of machine or artificial intelligence. Journal articles: seminars at the University of Moscow; widespread recognitions of the need for an interdisciplinary approach; professional writing on machine intelligence (Lyapunov A. 1960), (Lyapunov-Sobolev 1958); the Scientific Council on Cybernetics within the Soviet Academy of Sciences (BERG A. I. 1960); an increase in available machine time until recently in short supply; and articles on non-numerical computer applications to game playing, deciphering of manuscripts, medical diagnosis and musical composition; all point in the direction of increasing activities in the area of machine and artificial intelligence. In a recent interview (Feb. 1964) the late Norbert Wiener of MIT confirmed, on a basis of his personal visits to the Soviet Union, that the Soviets were placing great emphasis on computers and computer sciences. He reports active computer institutes in Kiev, Leningrad, Yerevan in Armenia, Tiflis in Sammarkand, in Tashkent, Novosibirsk and probably in many other centers. In Dr. Wiener's opinion they are slightly behind the U.S. in hardware but significantly ahead of us in the theoretical aspects of automatization (Wiener N. 1964).

4.0 MICRO AND MOLECULAR ELECTRONICS-IMPACT ON FUTURE SYSTEMS

Molecular electronics-Microelectronics-Materials research-Inorganic, organic-New functional devices. Future impact on military and information handling systems-System capabilities, structure, reliability, invulnerability, mobility.- Optical, electro-optical computer applications-Packing densities $10^9/in^3$ and feasibility of micro-space, myriad equilibria devices-Direction research.

4.1 Military System Implications

The trend to miniaturization of electronic components (microelectronics) has great import for information handling systems. In the coming decades, it will affect sensor and collection areas, data transmission, data processing, display, decision and control areas of information, intelligence and command and control systems. At present in its infancy and characterized by high manufacturing costs, trends indicate cost, weight, and size reductions and revolutionary changes affecting electronic system capabilities, structure, techniques, and equipment.

Microelectronics may be generally defined as the design, development and production of systems to perform electronic functions with components which are a number of magnitudes smaller than conventional components. The field has important implications for increased system, subsystem and component reliability, for system decentralization, mobility, and increased invulnerability (Wilcox - Mann 1962). Promising new developments in areas of "functional block" devices are arising (Keonjian E. 1963), (Tomaino M. F. 1963). These stem from work in molecular electronics and materials research. In the next two decades, probabilities are considered highly favorable to the development of new properties of materials (inorganic, organic) applicable to the performance of new and presently unknown functions having direct applications in the informational science areas of sensing, transmission, processing, display and control.

Microelectronic is considered as encompassing:

(1) Compact packaging of miniaturized, discrete circuit components.

(2) Thin film circuits in which resistors, capacitors and inter-connections are formed by thin film deposition techniques on

a supporting base, with separate, active elements such as diodes or transistors integrated into the circuit by placing them on or recessing them in the supporting base or substrate.

(3) Semiconductor integrated circuits formed directly on or within a semiconductor base. The base performs one or more active functions in the circuit. Resistors, capacitors and interconnections are formed by thin film, diffusion, evaporation and other techniques. Thus a single wafer of silicon may perform the functions of amplifier, logic element, oscillator, counter or other desired electronic function.

In addition to the above three categories of microelectronics, a new and advanced concept of "molecular electronics" is evolving in which a single (monolithic) block of material is grown and processed in such a manner that molecular domains are set up which perform the functions of a complete circuit. Evolving from solid state physics, these developments are being supported by materials research (Tomaino M. F. 1963). See figure 6. They show great promise and in the coming two decades can be expected to answer many present circuit and system problems and problems arising from new, future, environmental conditions and demands.

The following material gives a simplified description and a basic picture of the range and categories of present microelectronic activities.

4.2 Miniaturized, Discrete Component Packaging

The first and earliest developed technique was the packaging of miniaturized circuit components. Packaging techniques include wafer layer, cordwood, and recessed pellet constructions. The micromodule packaging technique uses stacked wafers carrying miniaturized components. Typically the wafers measure .3 x .3 x .02 inches. Component densities of 200 parts per cubic inch are operationally feasible. Figure 2 shows an example of "cordwood" packaging of miniaturized components.

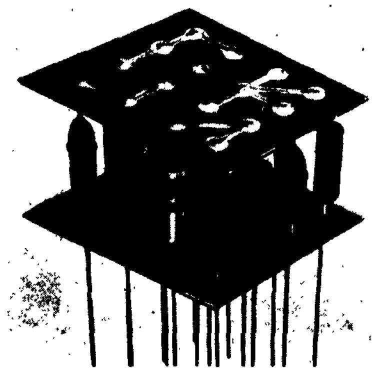

FIG. 2 - MINIATURIZATION-DISCRETE COMPONENT PACKAGING.

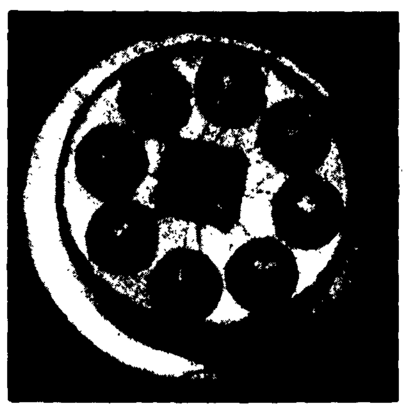

FIG. 3 - MICROELECTRONICS-THIN FILM INTEGRATED CIRCUIT.

The major problem centers on inter and intra wiring of these packaged modules and the long term reliability of the interconnections. Electron beam microwelding has solved some aspects of the problem. This discrete component technique is in wide use where ultra miniaturization is not required. In conjunction with new polyweld interconnection techniques, it is in use on radio altimeter systems, in the TFX inertial guidance systems and the 'Phoenix' missile computer. (LaFond C.D. 1964).

Thin Film Integrated Circuits

The next step was the development of techniques for producing resistors, capacitors and intercomponent wiring by the deposition of thin films (spraying, sputtering, evaporation, etc.) on a base or substrate. Separate active components (diodes, transistors, etc.) are integrated with the thin film connections. Component densities of 2000 parts per cubic inch have been achieved with high operational reliability figures. One problem has been achieving accurate resistive and capacitative values using the thin film deposition technique. This problem is being solved with improved, variable control of deposition film depth and width. Figure 3 illustrates a thin film integrated circuit. The first mass application of the technique by a large computer manufacturer is the reported new line designs of IBM. These new computers to be available in 1964 are reported to be smaller, faster and approximately half the price of earlier, comparable equipment (Drohan J. F. 1964). Philco and Motorola are also reported working in this area with expectations of competitive activities in early 1964.

The most recent development in thin film techniques is the deposition of active elements and thus the elimination of the necessity of wiring in separate, individual miniaturized circuit components. Varistors, oscillators, amplifiers, photoconductive and memory devices are presently in promising experimental stages. Introduction of active, thin film devices on a realistic scale is generally predicted in 3 to 5 years. The Bureau of Naval Weapons is playing an important and active role in the field.(Feldman C. 1964). An extremely important consideration is the increased invulnerability of thin film active devices to nuclear radiation. (Fowler A.1964), (Hogan C.1964).

Another technique being investigated by Stanford Research Institute is producing promising results. High Q filters, light detectors and light generating devices have been demonstrated. The devices are being fabricated from a highly radiation resistant refractory material (Molybdenum on aluminum Oxide) in a metal deposition technique. Very high packing densities are predicted. One of the advantages of the technique is that the devices are self forming, very much like electrolytic capacitors (LaFond C. D. 1964). The elimination of semiconductor material is expected to give greater invulnerability to radiation, yet retain thin film flexibility.

Some mention should be made here of the metal oxide semiconductor developed by RCA. It is a three electrode version of the insulated gate, field effect transistor and can be made to switch, amplify and control its output in a manner similar to a pentode. The microminiaturization technique permits 2,000 of these devices to be formed on a one inch diameter silicon wafer thus offering a single unit which can perform any required digital function by simply adding one layer of wiring (LaFond C. D. 1964).

4.3 Semiconductor Integrated Circuits

Two approaches are being taken to semiconductor integrated circuits, the multi-chip and the monolithic or single crystal approaches.

(1) In the technique, called by some the hybrid integrated circuit and by others, the multi-chip technique, active circuit components are formed on minute chips of active material (silicon for example). These chips are then integrated into the thin film circuitry of resistors, capacitors and interconnections which have been layed down by deposition techniques on a ceramic base. Although processing steps are detailed and numerous, the technique lends flexibility to design and permits the formation of very complex circuits with high component densities. One firm quotes densities of a million parts per cubic foot. Figure 4 illustrates the multi-chip or hybrid integrated circuit approach. Note that individual circuit components can still be differentiated in this technique and thus multi-chip circuits can be breadboarded.

(2) In the monolithic semiconductor integrated technique, the device is formed from a single slice of semiconductor material a few mils in thickness. This monolithic base in addition to its support function, performs active circuit functions which eliminates the necessity for wiring additional elements or chips

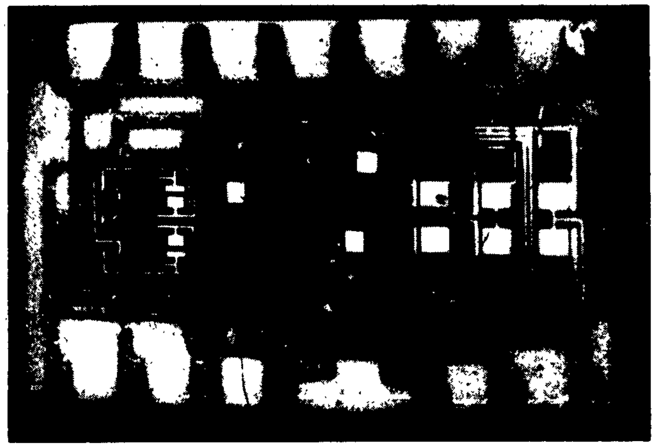

FIG. 4 - HYBRID MULTI-CHIP INTEGRATED TECHNIQUES

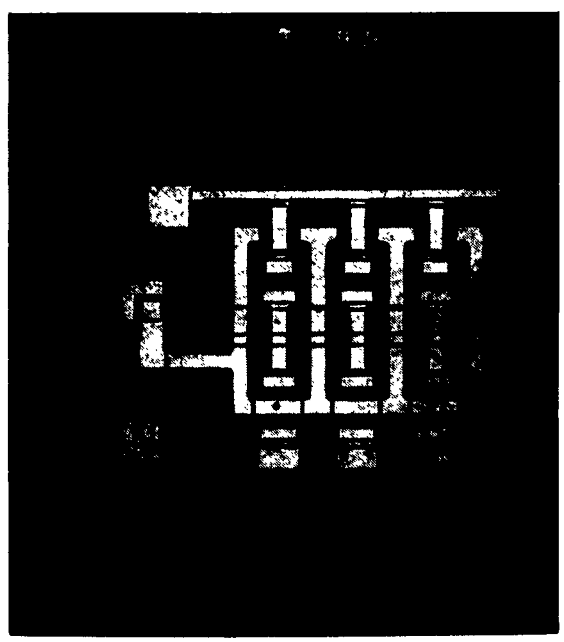

FIG. 5 - MICROPHOTOGRAPH-SEMICONDUCTOR INTEGRATED CIRCUIT

into the circuit (diodes, transistors, etc.). Thin film depositions directly on this active base form resistors, capacitors, and interconnecting circuits. The completed, processed slice is capable of performing complex electronic functions; the performance for example of a three stage amplifier, a series of computer logic functions, or analog to digital conversions. The term "solidcircuits" is also used in referring to these devices.

With the elimination of separate circuit components, manufacturing processes, though complex, are reduced to the handling of a single unit. Tests indicate improved reliability figures. Continuing cost reductions are expected. Figure 5 shows a microphotograph of a semiconductor integrated circuit.

Both techniques are in a relatively early stage of development despite the fact that there are commercial products on the market of high reliability. Applications at present are mainly in the field of computer devices including counting and shifting, half adders, switching functions, and logic circuit devices. Firms working actively in the field include Texas Instrument, Signetics, Westinghouse, International Resistor, Sprague and others. With advances in the field of molecular electronics (see next section) these two approaches to semiconductor integrated circuits will probably be merged and further simplified in a functional block device, produced by specialized growing and molecular domain control techniques. One step in this direction is the so-called three dimensional (3D) microelectronic structures being developed by General Electric in which a single block of material is processed by epitaxial growths on already diffused substrates resulting in a crystal with conductive paths and junctions below the surface, with a lightly doped upper layer (Olsson R. G. 1964).

At the present time there is not too great a stir among equipment manufacturers in general as a result of developments in microelectronics. In the next two decades however, advanced research, improved manufacturing techniques, new functional device capabilities, new system concepts and applications, military requirements, increased reliability, reduced costs and increased competition will, with high probability, operate to initiate revolutionary changes. As to the critical factor of operational reliability, one source quotes field tests supporting the general statement that integrated circuits proved to be 100 times more reliable than conventional circuits. A lengthy series of tests by Fairchild indicated the extremely low failure rate of 0.004% per thousand hours at a 90% confidence level.

For military usages it is impossible to overemphasize the importance of invulnerability to radiation as a characteristic of microelectronic circuits. Ordinary semiconductors are vulnerable. Thin film techniques including active devices offer an improvement in higher resistance to nuclear radiation. The SRI (Stanford Research Institute) work on thin films using radiation resistant molybdenum/aluminum instead of semiconductor materials is of interest in this respect. In materials research, discussed in the next section, devices based on Gallium Arsenide show significant resistance to radiation. As shown in a later section, this material and other compounds of Gallium show great promise of producing devices of direct importance to electronic systems including information processing systems.

4.4 Molecular Electronics and Functional Devices

Before discussing this area, it should be noted that standardization in microelectronic terminology is a critical need. Definitions and distinctions of such terms as molecular electronics, semiconductor integrated circuits, solid circuits, functional blocks, etc., vary radically. One manufacturer's "molecular electronics" may be another's "integrated circuit." For the purposes of this report, molecular electronics is defined as that concept which seeks, through controlled growth, synthesis, modification and processing, to integrate desired functional capabilities into a solid block of material. Internal characteristics and properties of the solid are manipulated in order that phenomena occurring within and between domains of molecules will achieve the desired function (Tomaino M. F. 1963). The technique involves field phenomena and charge and spin effects at atomic and molecular levels within the material. The control of the molecular domains may demand, in the case of crystalline materials, specialized growing techniques. Functional elements already demonstrated included experimental forms of amplifiers, multivibrators and computer logic elements (Gilbert H. D. 1961). Research in this area concerns itself strongly with materials. A few concerns, at present engaged in integrated and semiconductor integrated techniques are researching the field. Effort levels are not available at this writing, but are believed to be less than moderate. Westinghouse is presently using the trade name "Molecular Electronics" for some of its products. Whether or not these devices fall within the definition used in this section is not presently known. Molecular electronics would seem to be the ultimate in solid circuit microelectronic technology. A close check should be kept on developments in the field and on its supporting field of materials research. The concept of producing "functional devices" which perform system functions directly and simply is of vital interest to all areas of system design. (Henkels H. W. 1962). One of the important results of such a trend will be the effect it will have on the conceptual patterns of the designer. Instead of thinking in terms of the organization of conventional circuit components (resistors, capacitors, diodes, etc.) the designer may operate at system level, organizing and integrating functional blocks thus achieving a higher level of system design.

One of the major problems in microelectronics, especially in integrated circuit areas, is that of interconnection. Thin film and evaporative techniques solve the wafer or slice wiring problem. However, the interconnection of a stack of wafers or of a number of functional units still offers a yield depressing production problem. Some interesting advances have been made in the area of optoelectronics which may solve this and other problems. This is the "light coupling" concept in which accurately controlled light beams serve as interconnections between functional units. Optoelectronics shows high promise of rapid development as a technique with innumerable applications (Crosstalk 1964).

With respect to advances in the information sciences involving biological analogies of information systems, neural networks, adalines, and other concepts of artificial intelligence, the analogy between minute chips of material which perform complete functions and the neurons and nodal biophysical mechanisms of the human nervous system should not be missed. Molecular electronics and its parent discipline, solid state physics, can be considered one of the important areas in which practical research efforts can be directed to problems of adaptivity, self-organization, and learning in complex systems. These problems involve concepts such as the billion gate computer (Ledley R. S. 1963), myriad equilibrium states, random elements in computers and receptive (learning) capabilities (Ashby W. R., June 1963). From micro and molecular electronics will stem further developments of devices such as the neuristor, the memistor, and perceptrons, now playing important roles in pattern perception and trainable (learning) networks.

One critical obstacle to the advance of the trainable, learning machine concept is the purely physical problem of microspace incorporation of vast numbers of equilibrium devices (the clean slate concept) upon which can be imprinted, the patterns of the machines "experiences" in learning i.e., its "training". In terms of both size and function, the next two decades of materials, molecular and functional device research may well meet the demands of associative and adaptive mechanisms characteristic of certain basic learning patterns. No one expects to duplicate the human brain, but research advances in the information sciences indicate that extremely useful physical analogies of its simpler functional mechanisms can be achieved. In this respect it is of interest to note that parts densities in the human brain are believed to be of the order of 10^8 per cubic inch (Wallmark-Marcus 1962). A fundamental limit for packing densities of semiconductor devices is of the order of 10^9 parts per cubic inch (Keonjian E. 1963). As to functional capabilities, one cannot dismiss the growing achievements of the neural network simulation embodied in the "adaline" or adaptive linear network which has been taught and performs basic tasks in weather predicting, language and voice recognition and control. (Widrow B. 1962) (Widrow B. 1963).

5.0 MATERIALS RESEARCH-FUNCTIONAL DEVICES-INORGANIC AND ORGANIC MATERIALS.

5.1 Exploitation of New Phenomena.

Materials research in support of molecular electronics and functional devices is becoming continuously more active. It concerns itself with the basic properties and characteristics of materials with emphasis on their capabilities of energy emission, resistivity, conductivity, magnetic phenomena and energy control. Specifically of interest are materials manifesting the properties of semiconductivity, photoconductivity, superconductivity, dielectric, magnetic, ferroelectric; thermoelectric, piezoelectric, electro-luminescence, luminescence and coherent light emission. The trend is to exploit new materials and new phenomena while further exploring the nature and characteristics of presently known materials phenomena (Kestigan-Tombs 1963) (Stanford J. 1963). Research in materials is being pushed in directions of both higher and lower "band gap" materials (higher energy separation between valence and conduction bands). Abundant evidence supports the expectation that materials research will turn up new elements, compounds, and alloys offering possibilities for new functional capabilities and devices in areas such as opto-electronics, opto-electro-magnetics, piezoelectrics, superconductors, optical frequency detectors and presently unknown multi-function devices. These areas of physical phenomena and functional devices have direct applications in military systems involving spectral detection, transmission, data processing, information storage, retrieval, display and environmental control functions.

At the February 1964 I. E. E. E. International Solid State Circuits Conference in Philadelphia, a number of papers and described experiments indicated advances in the field of opto-electronics including areas of optical detection, optical communication, receivers, a solid state version of the multiplier phototube, and discussion of potential advantages of optical computers. These papers and discussions contrasted with the expressed opinion of Dr. Casimir, director of Phillips Research Labs., at Eindhoven who questioned whether research would continue to pay off in new electronic devices. It would seem that the question has been answered by the advances being made in integrated circuits, functional devices, the potential resources of areas such as materials research, and the pressing motivation given to all research areas by technological requirements in innumerable fields including information, command and control and weapon systems.

The panel discussions reflected cynicism on the concept of the completely optical computer. The panel, however, seemed in agreement on the importance and future of optical techniques and devices and their merging with traditional computer structures.

Research motivation and recognition of the importance of materials research were reflected in the call by J. R. Tippet of DOD for more cooperation between physical chemists and device and systems engineers. (Weber S. 1964)

5.2 Inorganic Materials

In inorganic materials, research interest centers on groups II, III, IV and V of the periodic table of chemical elements and on compounds formed by their combinations. The table below shows these groups.

Periodic Table Group Number	Member Elements
III	Boron, Aluminum, Galiium and Indium.
V	Nitrogen, Phosphorus, Arsenic, Antimony and Bismuth.
II	Beryllium, Magnesium, Zinc, Cadmium, and Mercury.
VI	Oxygen, Sulfur, Selenium, Tellurium.
IV	Carbon, Silicon, Germanium, Tin and Lead.

Up to the present time the elements in group IV have been playing the important role in terms of producing useful devices. Present research now however is showing that substances formed by combinations of the paired groups of elements shown above exhibit new and functionally important physical characteristics. These characteristics incorporated into microelectronic and functional devices may be the answer to many of the problems we are now faced with in the advancing information sciences.

The chart of Figure 6 on materials research relates the periodic table element groups (II, III, IV, V), whose elements and compounds are presently of interest to research efforts, to the devices being produced. It further relates these devices to application areas. As the chart indicates, research efforts are resulting in the production of an amazing number of new, advanced devices, some in experimental stages, some in actual field use. It suggests strongly, the great promise of materials research in unveiling new concepts, new devices and new areas of application (Tomaino M. F. 1963). In the history of much developmental work, it is of interest to note that in many cases, the existence of a new functional capability, or a device incorporating the capability, generates its own area of application. It is on a similar basis, that pure research often pays off in unlooked for, practical applications.

The chart emphasizes research and experimental work on compounds of gallium, cadmium, niobium and silicon. Research on these materials is presently producing results whose continuing development will have significant effects on system concepts, design, operational capabilities and characteristics of information, intelligence and command and control systems. Exploitation of new phenomena and new functional devices may permit system concept and design activities to operate at higher levels than the traditional component level; new capabilities will directly affect operational patterns including adaptivity and self organizational characteristics; microminiaturization will lend increased mobility, afford decentralization capabilities, and confer greater invulnerability through a physically and economically realizable redundancy.

Compounds of Gallium are proving to be particularly fertile sources of useful characteristics and devices. Notable is the rapidly developing semiconductor laser which is presently operating in an experimental form. It requires no pumping, and is easily modulated by the simple variation of input current. Gallium arsenide in addition to its wide variety of device applications manifests a high resistance to nuclear radiation, a characteristic vital to functional devices for military applications. Security closes off detailed discussion of evaluated effects of radiation on solid state and integrated circuitry. However, published data indicates that interfering signals are generated at radiation levels of the order of 10^8 Roentgens/sec (Gamma) and cessation of equipment operation for many circuits at neutron doses above

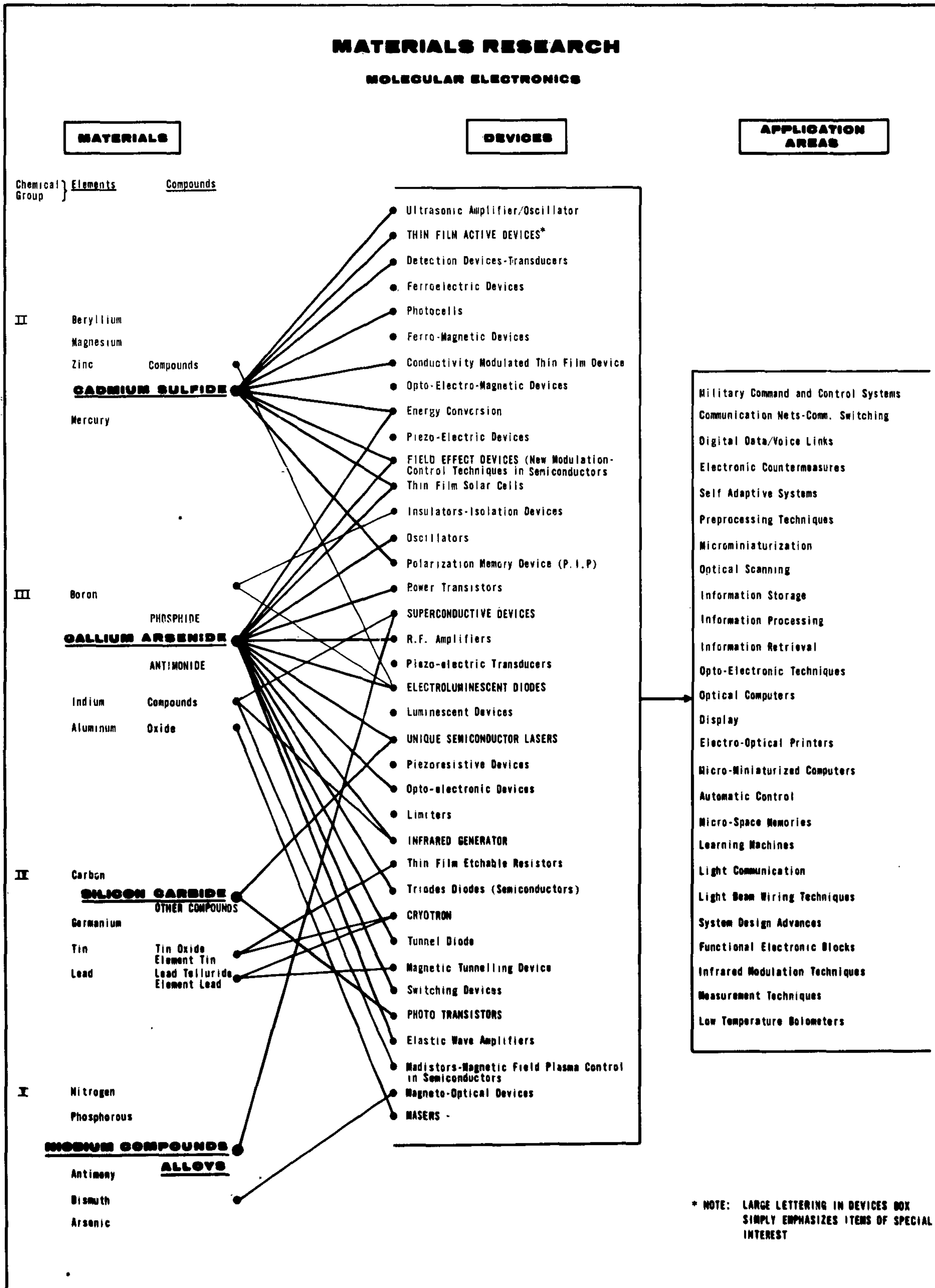

FIG. 6 - MATERIALS RESEARCH AND SYSTEM APPLICATION AREAS

$3x10^{14}$ neutrons/cm^2. In combination, such radiation, at varying distances, would cause malfunctioning of all types of computers and electronic circuitry using traditional integrated circuitry. (La Fond C.D. 1964)

No attempt has been made to make the materials research chart comprehensive. Although efforts are less intense in group elements and compounds other than those discussed above, there are experimental results of significance, some of which are shown in light lines on the chart. All elements of the four periodic groups represent a rich resource in terms of continued and expanded research.

Research directions should include the following:

1. Study and analysis of the nature of phenomena supporting presently operating devices. (Example-luminescense, light diodes).
2. Relation of the nature of the phenomena to the nature of the function it serves in order to generate analogies and new areas of possible application.
3. Study and analysis of atomic and molecular characteristics of the periodic group elements and compounds associated with particular phenomena. This would include relationships of phenomenological characteristics and high and low band gaps (i.e., energy separation of valence and conduction bands); symmetry of energy band structures.

5.3 Organic Materials

Research areas in organic materials are relatively untouched. These materials are compounds whose basic building blocks are carbon, nitrogen and hydrogen. Several of the rare earths (so called chelates) have been recently shown to emit coherent radiation. There are obstacles which must be overcome but the development is new and much can be expected. Possibilities exist for organic photoconductors, transducers, inductors and light and color modulating devices. Organic materials have great advantages in structure, being soft, tough, impact resistant and extensible.

Suggested research approaches include as a first phase the determination of what possible functions the material could achieve, rather than searching for materials with specific functions. Useful properties might include acoustic interactions, infrared transitions, photochromic, electrochromatic, dielectric, piezoelectric and piezoresistive capabilities.

6.0 MACHINE LANGUAGE TRANSLATION.

World-wide research in Machine translation-Present quality rough but useful-Brief history of M. T. Early research directions-The IBM Russian/ English system-The Soviet Belaskaya system-Organization of Soviet MT research-Present U.S. research trends-The cyclic method-Man/machine feedback-The semantic problem-Search for linguistic universals.

6.1 Present Status-Problem of Quality Translation.

Machine translation (MT) is presently an area of active, world-wide research (NBS 1963) characterized by (1) a number of experimental translation systems producing useful, but rough translations in half a dozen languages, (2) a relatively large corps of workers who believe in the critical need to break down world-wide language barriers on a large scale, and (3) a few severe critics who are of the stated opinion that high quality translation by machine will never be a reality.

A question arises as to just what constitutes high quality. If we are discussing the translation of Marcel Proust's "Remembrances of Things Past," the subtle shades of meaning will be translated in numerous ways by the best of human translators. If we are discussing translations of works in science, economics, politics and other disciplines we may approach closer to agreement between human translators. The same pattern applies to machines. When one speaks of quality translation, it is helpful to state the type of material. Working in a single language and restricting the translation area to a single discipline in that language, (physics, political science, general news coverage etc.) reduces the problem tasks to reasonable proportions. In dealing with the overwhelming mass of the world's production of information in any field, we can and are at present accepting translations which are highly useful but certainly less than "quality" translations. Despite the examples of carefully chosen syntactic "pitfalls" which defy unambiguous translation by presently operating systems, it is highly probable that M. T. is here to stay and that the next decade or two will see significant improvements in the product.

The following material covers the early history of machine translation with indications of the research areas, present activities in terms of several examples of operating translation systems and areas of research, a discussion of Soviet activities in the field with a discussion of their 'Belaskya' system, and finally, research areas being explored.

6.2 History and Early Research Directions

A brief summation of the history of Machine Translation (M. T.) will serve to foreshadow research directions, trends, and establish a perspective and background against which some estimate may be made of the rate of progress, and of continuing problem areas. There has been interest and activity in the field of mechanical translation since 1947 when a code for dictionary translation was worked out as a result of the collaboration between Warren Weaver of the Rockefeller Foundation, A. D. Booth of London Birkbeck College Computation Laboratory and U. H. V. Britten of the Institute for Advanced Study at Princeton. In 1949 a memorandum written by Warren Weaver entitled "Translation," was sent to some 200 scholars working in various fields. It suggested the possibility of high-speed mass translation of scientific material through the use of electronic computers. It is generally agreed that this paper strongly influenced the development of research in the U.S. and its subsequent spread to Europe, the U.S.S.R. and Japan. In the same year, research activities in M. T. were inaugurated at the University of Washington, University of California and at the Massachusetts Institute of Technology. In 1951, machine aided language research was called for by the publication of a specific "Proposal for Mechanical Resolution of German Syntax Patterns," by V. Oswald and S. L. Fletcher. The SWAC computer at the National Bureau of Standards was used in this work (Taube M. 1963). In 1952 the Rockefeller Foundation supported the First International Conference on Machine Translation which was held at the Massachusetts Institute of Technology. At the conclusion of the conference, general agreement seemed to indicate two specific directions of research to be taken. (1) The need for construction of an automatic dictionary, and (2) a theoretical approach in the form of syntactical studies as a basis of computer programming of all operations involved in machine translation. At the present time, more than a decade later, these two areas are still central in advanced research studies. In 1954 an IBM-701 was used in a demonstration of the translation of Russian into English using six basic syntactic rules and a very limited vocabulary of 250 words. Interest in M. T. spread rapidly. In 1955 the Soviet Union initiated experimental and theoretical work in M. T.

The following 5 years saw the Second International Conference at M.I. T. (1956), the development in 1957 of a photoscopic memory device with practically unlimited storage capacity and rapid access time (Reifler E. 1962), the first All Union Conference on M. T. at Moscow (1958), the UNESCO supported International Conference on Information Processing at which papers on M. T. were presented by a half dozen different nations (1959), the National Symposium on Machine Translation at Los Angeles in February of 1960*, and in 1961 the M. T. Symposium at Teddington England and the Moscow Symposium of the Institute of Scientific Information on Machine Translation and Pattern Recognition.

6.3 Present Activities

At the present time a world-wide research activity is current (NBS 1963). Since 1959 a high speed computing machine system for the translation of Russian into English has been regularly producing a rough, but perfectly readable translation of PRAVDA. This experimental system was developed by IBM (Dr. G. W. King) for the U.S. Air Force. A glass disk 10 inches in diameter contains a dictionary of 50,000 binary coded words and phrases on circular tracks roughly .4 inch in width. The coded entries are represented by black and clear blocks, each .000333 inches square. The Russian input word flow is compared to the word/phrase dictionary (which is being expanded to 500,000 entries). When a match is found on the rapidly rotating disk the English equivalent is printed out via a high speed register and output typewriter. An interesting aspect is that when an input Russian word is not found on the disk, it is translated into Roman characters and printed out in red on the hard copy thus automatically recording the specific need for additional dictionary vocabulary elements. The system (Mark II) is a working device of practical usefulness as well as continuing value as a research tool. The system emphasizes the empirical approach in its automatic dictionary of words and idioms with dependance on large capacity, comprehensiveness and

* ONR supported

rapid access. One major drawback pinpoints a critical need for automatic reading techniques to eliminate the slow and laborious step of manual card punching or tape preparation of input material (Hilton A. M. 1964). Harvard Computation Laboratory is engaged in perfecting the compilation of a Russian-English dictionary under the sponsorship of the National Science Foundation, the U.S.A.F. and the Harvard Foundation for Advanced Study and Research. Essentially the automatic dictionary is a research tool to effect smoother, more accurate translations through advanced development of syntactic algorithms. Its UNIVAC system combines the empirical, dictionary approach with structural and linguistic aspects. At M.I.T. a programming language has been developed for research use by linguists having little or no training in computer programming. The language is designed for use with a general purpose computing machine. In the Soviet Union the Belskaya system is producing what has been reported as remarkably smooth English-Russian translations. Detailed comparative structural analysis of the pair of languages is considered to be responsible for the improved quality of the translations. In Tokyo, English-Japanese translations are being produced by a fully transistorized computing machine. The system combines the empirical (dictionary) and the structural-analytic methods. There is no information at hand as to the characteristics of its product.

6.4 Soviet Activities-Organization-Systems-Research

Worthy of special note is the M. T. research activities and their organization in the U.S.S.R. The work is headed by The Institute of Linguistic Research, which beside lending qualified linguists to research groups, oversees the work of four groups: The Institute of Mechanics, The Electromodelling Laboratory, The Institute of Mathematics and The Experimental Laboratory for Machine Translation. In 1955 two pairs of languages, English-Russian and French-Russian were being studied. In 1960 twenty pairs of languages were being worked on. The Soviet approach emphasizes glossary development, linguistic analysis, intermediary languages, and semantic studies. Glossary development problems are kept to practical and workable proportions by limiting the work to selected disciplines (Geology, Mathematics, etc.). The glossaries are text developed not dictionary generated.

Linguistic and language structural studies are believed to be mainly approached by manual methods and handled by relatively large groups of workers. The intimate knowledge of structural and syntactic problems gained through manual methods may pay well later. Such an approach has probably been directed by a lack of sufficient computer facilities. Interest and work in Intermediary Languages probably stems from the difficulties met with in the development of satisfactory algorithmic forms and methods. Evidence indicates that this work too, has been profitable in terms of increased knowledge of general language structures and in knowledge directly applicable to advanced concepts in algorithmic processes and computer programming languages. It also probably led to an earlier facing of the complex problems in semantic areas which are presently considered as critical barriers to a more rapid progress in M. T.

When computer facilities equal to those in the United States become available in the U.S.S.R., it is possible that significant Soviet breakthroughs in machine translation will be realized. At the present time, the best Soviet system is that of Belskaya of the Academy of Sciences of the U.S.S.R. The system, is used mainly for English to Russian translations, but also produces Russian texts from German, Chinese and Japanese. It uses algorithmic procedures based upon a combination of empirical (dictionary) and theoretical methods involving semantics, grammatical analysis and synthesis. The approach has been generated from detailed structural studies of the language pairs involved and decisions based upon comparisons of these structural classifications. It has been reported that translations are adequate, relatively smooth and require no post-editing.

6.5 Present Trends in Research

The most recent literature in the area of M. T. research (Garvin P. L. 1963) indicates a need for a stronger foundation in modern linguistic science before laws can be derived upon which to base algorithms significant to the wide range of M. T. problems met in the translation of target languages of major interest. Modern linguistics is taking new directions from the older, traditional aspects which centered around the history of languages (philology) and the history of words, word formations and expressions (etymology). The modern trend is to the study of language as a phenomena without regard to the historical backgrounds. The center of interest is language structure and nature. The approach is through analysis and orderly description. (Garvin P. 1963) Modern linguistic research should be conducted on three levels:

1. Morphological, involving the analysis of words and word forms. This lays the groundwork for syntactical analysis.
2. Syntactical, or the analysis of sentences and the relations between the forms which occur within them. This amounts to structural analysis in terms of dependency theory and classification of dependency links.
3. Semantic theory and the determination of "meaning." Semantics deals with the relations between language symbols, structure, and reality in terms of cognitive and cultural meaning.

Semantic theory represents an area in which the least progress has been made. Research efforts directly in the area have been relatively few. No adequate formulation of semantic structure is available at present, which satisfies our M. T. needs. (Hays D. G. 1963) The phenomena of multiple meaning must be probed and its ranges and boundaries drawn. Syntax of course is needed to reveal the semantic connections within the sentences. Semantic and syntactical relationships are not, however, identical and a determination must be made as to how many different semantic relationships can be indicated by each function. Textual methods, as used in morphological and syntactical studies can be used in combination with linguists native to the language. Cyclic machine methods would be involved. Organizing principles for semantic information are a critical need. Until semantic theory and research have progressed significantly, M. T. programs will be characterized by some degree of ambiguity, resolvable only by alternative sentences or by post-editing.

The search for language universals is another important area. This takes the direction of building language models. Simplicity and economy in model structural design and in classification are necessary. Illustrative of some of the characteristics of the model would be multilevel structure, recursiveness, simplicity within each level, inclusion of laws of occurrence order and multidimensional classifications of recurrent word classes (Garvin-Karush 1963). We are not referring to mathematical models. It seems to be widely accepted that mathematics or mathematical models in language research are wide of the mark and cannot at present replace empirical and heuristic methodologies in modeling or in general research. Only after considerable progress has been made in natural language research, and after natural language units, structures, and interrelationships have been ascertained by inductive methods and verified by cyclic machine methods, may conditions be met for the application of mathematics to natural languages. Even then insuperable difficulties may be met. As Von Neuman has stated, natural language and human thought are not inherently mathematical. It is possible in fact that the complexities and subtleties of natural language may be suggestive of new modes of thought to the mathematician (Garvin-Karush 1963). Theoretical approaches and empirical methodologies will play an important role for possibly another decade.

One critical need at the present time is a high speed, automatic input reading device which would eliminate the laborious and time-consuming card punching or tape preparation step. Pattern recognition techniques capable of handling a variety of fonts would be required. Ideally it should be possible to handle hand-written materials. Present state of the art is not equal to this problem. The near future may produce a device capable of handling one or a limited number of standardized fonts. Such a limitation would, however, be critical as far as flexibility and speed in handling a variety of foreign materials for translation.

An interesting aspect of present translating procedures is the 'cyclic' method which permits coupling machine operations with the intuitive, heuristic capabilities of linguists. The machine's first translation run is carefully studied by linguists who analyze errors, ambiguities, structural malformations, etc., and then write transformations in terms of corrective instructions into the directive program. The machine then produces another translation. This cycle is repeated as required until the translation is satisfactory. Once the machine has "learned" in this manner it will never produce that type of linguistic error again. One problem is that of obtaining a sufficient number of language samples involving wide varieties of linguistic problems, terminologies, idioms, etc. Machine translation dictionaries must be developed from such sample texts. The work should be restricted to one language and one discipline in that language. This coupling of man and machine in a corrective feedback loop illustrates one of the promising directions in merging man and machine capabilities. It indicates the importance of a more detailed knowledge of our own problem solving processes including intuitive patterns which once clarified, could be incorporated into the computer resulting in improved, adaptive machine capabilities.

7.0 NON-CONVENTIONAL COMPUTERS-OPTICAL TECHNIQUES IN INFORMATION PROCESSING-CONVENTIONAL COMPUTERS AND NEW TECHNIQUES.

Possible future trend away from the von Neuman calculator-Complex problems and the search for new internal organizational principles and structures-Non-numerical problems and the "inductive"machine-Non-conventional computers-Optical techniques in information processing-Light beam circuitry-Semi-conductor lasers-Optical transfer of information-Conventional computers-Multi-access systems-Parallel concurrent computers-New man/machine intercommunication approaches-Sketch Pad-The continuing major problem of languages.

7.1 Advanced Non-Conventional Computers.

The future trend in computers may be away from the present von Neuman calculator and its typical binary "yes," "no" logic and toward a machine whose internal structure has inherent characteristics, especially directed to the solution of non-numerical problems. One example of this trend is the IBM interest in the possibilities of a machine whose internal organization and physical structure would reflect the demands of advanced heuristic operational patterns. Such a machine would manifest inductive as well as deductive characteristics. It would display to some presently unknown degree, capabilities for improving its performance (learning); defining complex problems and solution approaches; weighting alternatives; and acting as an aid in decision making areas. It would be capable of solving a wide range of non-numerical problems and problems characterized by vast numbers of variables, now unsolvable by conventional computers despite fantastic speeds and capacities. Based on the problem solving scope and capabilities of present heuristic programming, the heuristically structured computer promises to be an important advance.

There are a number of research efforts involving new organizational and modal concepts of computer operation. These efforts are important evidence of the need, not for bigger and faster conventional computers, but for essentially simpler computers if this is possible, based upon new internal operational concepts. The need is to rise above the problem solving and man/machine intercommunication plateau we have reached with the conventional computer. Further, the need is to answer the wide ranges of non-numerical (and numerical) problems arising from this era's complex systems and man/machine interrelationships.

These research efforts have in common, the important characteristic of a directed and systematic search for new internal organizational principles and structures. They include the interesting and promising concepts of (1) the "Fixed Plus Variable structured computer" whose characteristics reflect the variational possibilities of physical as well as logical element interconnection "patterns" within the machine (Dr. G. Estrin of UCLA); (2) the so-called "Holland Machine" which involves cooperative problem solving activities of of physically separated (optimally distributed) multi-elements linked in internal communication nets (Dr. J.H. Holland of the University of Michigan); and (3) a computer whose structure and elements display analogies to biological nervous system organization. Research on this is in process at Stanford under the direction of Dr. Hewitt Crane. The system involves the use of neuristors (electronic analogies of neurons) and the concept of local energy (information) flow along a network in a manner analogous to information flow in a biological system.

These are important research efforts. The future machine may be a combination of several of the concepts above. An example might be the incorporation into the Fixed Plus Variable structured computer of neurophysiological concepts inherent in the neuristor-energy flow type.

These directions in computer research are compatible with the concepts of the late Dr. Norbert Wiener of MIT (Wiener N. 1964). The trend in research, in solving the pressing non-numerical problems of associative memory, associative storage and retrieval, pattern recognition, machine translation, signal identification and closer, less formal man/machine interrelationships is to move in the direction of new internal machine modes and structures, toward what has been termed the "inductive" machine in contrast to the deductive, von Neuman calculator.

7.2 Optical techniques in information processing-The Optical Computer.

Optical Techniques -

The continual demand for higher computer speeds, capacities, flexibility and reliability motivates the search for advances in computer software, hardware and new basic design principles and approaches. With the continuing development of lasers, fibre optics, light generating diodes and light beam circuitry concepts it was inevitable that optical techniques would invade information processing areas. There has been a wide range of development efforts in the area of optical data processing but little coordination outside of the beneficial effects of optical information processing symposiums in 1962 and 1963*.

Optical transfer of information is accomplished with the speed of light and has the tremendous advantage of parallel processing; that is, the operation proceeds simultaneously for every element in the total information array (image). A computer endowed with these and other characteristics basic to optical methods might be capable of answering the continually growing demands for greater speeds, capacities and functional capabilities.

It is highly probable in the coming decade that diverse optical techniques will develop and find increasing application in various areas of information processing. Such techniques will probably include light generating diodes, semiconductor lasers, fiber optics, light beam circuitry, light beam triggered logic, new mass storage techniques, advanced optical scanning concepts and specialized display modes. The inherent advantageous characteristics of optical phenomena with respect to information handling systems are such that it would seem inevitable that an "optical" computer will evolve from the growing classes of applicable optical techniques and devices. Although it is not on the immediate horizon, developments suggest that at least experimental forms will be operative within a decade or two. An important and more immediate probability is that optical and optoelectronic techniques will increasingly invade information processing and communication systems to their advantage. From this may stem presently unknown system flexibilities and capabilities and ultimately the feasibility and possibility of an all optical computer. In this

* IBS-ONR supported.

period, a clearer picture may develop of the need for such a computer, and what its actual technical and economic advantages might be over the evolving forms of our present computers both conventional and nonconventional.

One critical need which may be answered in the near future by optical techniques or a combination of electro-optical techniques is machine translations's great need for a rapid, efficient, automatic input reader which would eliminate the time, labor consuming, and unwieldy requirements of card punching or tape preparation of textual input materials.

It is of interest to note that information processing technologies including optical techniques and microelectronics have a common interest in materials research. Electronic, optoelectronic and opto-electronic-magnetic techniques and devices will be important to both technological areas. Materials manifesting characteristics related to light generation, electroluminescence, and coherent light generation, are of particular interest at present. Gallium arsenide is one of the promising and interesting substances which will play an increasingly important role. (See Section 5.2 Page 30).

A specific area of interest to information processing is optoelectronic logic and memory techniques. (Bray T. E. 1963) - Of paramount importance is the recent achievement of coherent light generation (laser action) by solid state devices similar to transistors. This advance represents an important step in the continuing development of optical data processing techniques. The laser's high frequency, narrow beam of coherent light, is capable of carrying fantastic amounts of information. It is possible for a single laser beam to carry the information content (radio and TV) of the entire radio frequency spectrum. The beam's characteristics of high energy, narrow beamwidth, and vast information carrying capacity point to the possibility of revolutionary applications in information processing, communications, and other areas of interest to the military. Computer to computer links capable of rapid emergency transfer of entire memory contents or links between data control and information retrieval centers are examples of applications. (Lessing L. 1963).

Much of the early developmental work (1962) in areas of light generating diodes and semiconductor lasers was accomplished by groups at General Electric (advanced semiconductor Lab Syracuse N. Y.), IBM, and Lincoln Laboratory. The advance from incoherent semiconductor light generation to coherent semiconductor lasers has been accomplished in the past year (1963). All the functions of the laser are now available from a tiny crystal, which when stimulated by an electrical current generates a coherent light beam. Information can be impressed on the radiated beam simply by modulating the applied current. This contrasts radically with the complex problems met with in the modulation of other forms of lasers. (Ruby rod or gas lasers). The semiconductor laser's coherent light beam can be tailored to any wavelength from mid-infrared to the visible simply by varying the ingredients of the semiconductor crystal. Potentially it can be designed to emit wavelengths ranging from 52, 000 Angstrom (A) to 5000A. A variety of semiconductor materials can be used. Gallium arsenide emits at 8400 A, Indium phosphide at 9100 A, Indium arsenide at 31, 000A and Indium antimonide at 52, 000A. Lasers have been made from all of these materials. A semiconductor laser just recently made at the General Electric Advanced Semiconductor Lab. (Syracuse, N. Y.) utilizes Gallium arsenide phosphide and emits its radiation beam in the visible spectrum as red light at the wavelength of 7000 A (QUIST T. M. 1964). Crystal laser operation in pulsed operational modes is obtainable at ordinary room temperatures. For continuous operation,however,cryogenic temperatures are necessary at present with one exception. A silicon carbide crystal laser has been fabricated by TYCO LABORATORIES which affords continuous (CW) operation at normal room temperatures. Notable is the fact that its coherent light beam is in the blue range. This means shorter wave length, higher energy concentration and better transmission properties in air and radically improved transmission in water. The generation of blue coherent light and the probable near future generation of coherent green light with its reportedly superior underwater transmission capabilities may have important significance for ASW operations in areas of laser radar and/or communication.

The Optical Computer

The general concept of a wholly optical computer is typically pictured as one in which the inputs would be modulated, information-carrying light beams, triggering laser action in fibre optic networks, to effect computation, information storage, processing, retrieval and other required information handling functions with the speed of light. The optical computer is the object of presently contracted research efforts, one of which is being fulfilled by

Radio Corporation of America for Rome Development Center. Other organizations working in the field of computer applicable optical techniques include Institut d'Optique University of Paris; Dept. Electrical Engineering, Syracuse University; Clapp, Bolt, Beranek and Newman, Inc.; American Optical Company; General Electric Computer Laboratory; Thompson Ramo Wooldridge Inc; General Telephone and Electronics Laboratories, Inc.; Stanford Research Institute; Cornell Aeronautical Laboratory Inc.; IBM; Sperry Rand Corp.; Computing Machine Laboratory University of Manchester England, and numerous others. (Pollock, Koester, Tippet 1963). No one knows when or if an optical computer will evolve. There is no clear picture of its total profile of possible advantages over present computers. The form of its language is unknown. If it does evolve it will move closer than any other device to the lightning speeds typical of human thought and learning processes.

The IEEE Conference* in Philadelphia in February 1964 had several panel discussions which included the topic of optical computers. In general the discussions reflected cynicism on the concept of the completely optical computer. They indicated great interest and optimism for future developments in optical techniques, their merging with traditional computers and their importance in information processing systems in general. Meanwhile these techniques are advancing rapidly. Their applications in data processing and information handling techniques are growing. Fiber optics, light generating diodes, lasers and semiconductor lasers have a bright future. Along with other molecular and functional devices, they are regarded in some circles as promising revolutionary changes in information processing, and communication systems.

7.3 Conventional Computers and New Techniques.

Significant advances in the field of conventional computers have been achieved in the past two years. An entire report could concern itself with the details. In general, the information is widely available and will not be enlarged

International Solid State Circuits Conference-IEEE-1964 upon here. Of note are the following trends. Increasing applications of computers are in evidence in the area of storage and retrieval of large volumes of data and information. This involves problems of language control and special modes of internal storage of data (Stevens M. 1964), (Borko H. 1964). The use of data interchange communication systems is widening. Computers are becoming major elements in large communication nets and in traffic handling communication switching centers for message handling, storing, switching and routing. Widening use of computer facilities will be achieved through multi-access on-line systems from multi-remote locations (Pickering et al 1964), (Dunn-Morrisey 1964). The MAC (Multiple Access Computer) project at MIT is an important example of this area of development. Other operating units are in everyday use at Systems Development Corp. research center at Santa Monica, California (an IBM SQ-32 system is used), at Stanford Research Institute, at the Laboratories of U. C. L. A. and at Carnegie Tech. (Pfeiffer J. 1964) The simultaneous use of the computer's diverse facilities at a number of remote locations is made possible through time sharing and multi-programming techniques. Access to the computer is switched through the users consoles at such high speeds that each user in effect seems actually to have continuous use of the facility. Another advanced but costly method of simultaneous computer use is the "parallel-Concurrent" computer exemplified by Control Data Corporation's latest computer, the 6600, which can run eleven programs simultaneously without time sharing techniques. Such a capability of course involves a huge complex of equipment units. Actually the 6600 consists of eleven independent computers, a central processor and ten peripheral and control processors. An important use is the solution of large magnitude scientific problems (Computer Design 1964).

In the opposite direction on the continuum of today's computers is the very significant effect of microelectronic techniques on the miniaturization of electronic computers. Desk size and hand-held sizes are becoming available with continually increasing memory and processing capabilities. As an example

*MAC also stands for 'Machine Aided Cognition' (Fano Robert M. 1964) of the effects of microelectronics and miniaturization trends, one computer presently available in 1964 weighs roughly 35 pounds, and has a volume of approximately seven tenths of a cubic foot. Its components are largely micro-electronic products. It has a 65, 000 word memory plus a so-called "scratch pad" memory. These developments are of interest where decentralization and mobility are requirements. They may have important applications at the lower levels of task force processing requirements. The smaller computers are reported as engendering a more direct, simpler and intimate relationship with the user, somewhat analogous to the use of desk calculators in solving various types of problems. It is possible that specialized types of these miniaturized computers will find a useful place in the processing of intelligence by individuals or by small groups of intelligence personnel.

There have been advances in the area of mass random access. Access time however is relatively slow (order of one quarter of a second) but not, of course, in comparison with tape systems where hundreds of feet may have to be run through in the sequentially stored material to access a single piece of data. On-line systems most fully realize the advantages of mass random access/storage devices. Problems slowing acceptance involve the complexities of translating present operating methods into an on-line system as well as effectively organizing data in the random access type of file. (Auerbach I. L. 1963)

An interesting development is the so-called "Sketchpad" which may in the future develop into an effective man/machine intercommunication mode of wider range and significance. At present it is being presented as a machine aid in design fields. The user writes with a light pen on the face of a CRT display device. Sketches can be drawn, perspectives manipulated, animation of rotating parts initiated, computer commands and requests for information given etc. As an alternative to light pen writing, the "Teager Board" (Dr. Herbert Teager of MIT) permits writing and sketching on paper placed upon a special plastic surface which transfers electrostatic charges to the writing pen as the writing and sketching progresses. These charges conducted to the computer through the writing instrument, causes the computer to produce the desired results. (Sutherland 1963)

Today's computer continues to be plagued by the major problem of language and man/machine intercommunication at a less rigid, costly, and complex level than conventional formal programming. Some advances have been made including specialized vocabularies in a particular discipline such as the Harvard development of a language for linguists in the area of machine translation, and the development of a specialized language for engineers called "STRESS" (Pfeiffer J. 1964). Reportedly, these simplified programming languages in restricted disciplines can be learned in a few hours and used in a relatively straightforward, simple manner by persons knowledgeable in the particular technical area.

There are interesting implications for intelligence and command and control systems in the man/machine intercommunication modes represented by 'Sketchpad' and by the area oriented, simplified programming approach. Both of these are actually in developmental stages. They should be watched for future developments. Consideration should be given to possible applications in intelligence and information processing and in command and control areas including machine aids to decision.

8.0 ADVANCED SYSTEM PROBLEMS- NEEDS- APPLICABLE RESEARCH AREAS.

This section of the report considers some of the problems and future needs of intelligence, information handling, and command and control systems in terms of the demands and possible threats of the 1970-80 era. It is not possible in this report to do more than briefly list some of these problems and needs and indicate currently active research areas having pertinence to the problems. The summary of the report will categorize those research areas whose scope and status are such that they show a high probability of answering wide ranges of system problems within the coming two decades.

8.1 Intelligence Collection

A. There is a critical need for a more complete and rapid coverage of enemy activity.

Reconnaissance equipment should be designed to operate in automatic modes at the earliest possible date. Such operation would include automatic scanning of the spectral ranges covered by known enemy weapon systems and recognition and identification of enemy weapon system signal characteristics. Emissions would be automatically detected, recorded, and filtered. Enemy's heat emissive equipment would trigger infrared recorders. Applications should be wide and include ASW, surface, air, amphibious, and space.

Research-Studies

Research and study areas which have direct application to the problems involved include the following: adaptive and self organizing principles, mechanisms and systems. A feasibility study should be made on present, promising developments in this area. The focus should be on possible practical applications to effective ECM automation.

Pattern recognition capabilities would be required in the signal identification and recognition phase. Relatively simple template comparison modes might be applicable depending upon the complexity of the wave forms. More advanced methods would be involved in the handling of ECM imagery.

These are areas of present research efforts which should be monitored. As research progresses, feasibility studies should be made on promising developments with direct focus on practical applicability to automated modes of ECM. Such a study should cover, among other details, the following: an analytical profile of the signal environment; an analysis of the nature and characteristics of the ECM products resulting from such an environment; analysis of ECM functions amenable to adaptive automation. Examples of such functions would include automatic scanning in frequency, step monitoring, signal identification, acceptance or rejection based on pattern recognition of signal waveform characteristics, signal conditioning, etc.; finally, correlation of these factual areas with adaptive and self-organizing principles, mechanisms, or systems in development, potentially capable of answering the technical problems involved.

The range of applications is wide and covers air, surface, sub-surface and amphibious uses. With a miniaturized, wide band video transmission capability which could be queried, such an automated ECM unit would be entirely independent and capable of "reporting" from normally impenetrable locations. One critically important application would be the reconnaissance satellite.

B. Need for Knowledge of Nature and Characteristics of Future Enemy Weapons Systems and Probable Signal Environment

There is a definite need for a continued study and analysis of directions and trends in enemy research and development in areas having possible implications for new or exotic weapon systems. Such a study would project the probable nature, characteristics and spectral ranges of such systems and give indication of the directions to be taken in the research and development of new modes and devices for the detection, identification and location of the systems whether electromagnetic, acoustical, optical, nuclear, chemical or other. The study materials would be mainly basic research activities, with statistical analysis of research tree associations which might indicate possible weapon system applications. Such a study would lend significant support to our predictive capabilities and produce broad indications as to whether the directions were crossing areas or products useful in aggression. The information would afford guidance in the nature and characteristics of required detection devices and in the direction which countermeasures research and development should take to effectively deal with possible threats.

8.2 Preprocessing Concepts-Needs-Applicable Research-Studies

A. Need for preprocessing capabilities, possibly at the collection site, to reduce overwhelming data volumes, reduce load on central processing functions, and increase the ratio of useful to available data.

1. Preprocessing is by nature a broad band filtering type of operation at an early stage in the collection process. It must be confined to simple routines, with care taken to avoid time or data loss. Automatic filtering to eliminate unreadable or nonessential data is one aspect. Preprocessing will increase the efficiency by which relevant information is obtained from available data. That is, increase the ratio of useful to available data. Preprocessing methods will probably include the following --

a. Discarding data with little or no relevance.

b. Organizing items of data in a systematic manner.

c. Transforming the data so its relevance could be more easily detected.

Study:

A detailed study would be necessary to determine the nature and characteristics of the ECM products in both the image and nonimage forming areas. This would serve to set the range of pattern recognition techniques required for simple elimination of unreadable data or data resulting from faulty operation. Organization of the data could be done on a platform attitude/ location/time basis with some method of coding this information directly on the taped or filmed data. To an extent these capabilities exist. Transformation of the data for increased relevance would have to be based on a feasibility study following the study of the nature and characteristics of the ECM products. The goal of reducing the increasingly overwhelming volumes of data may be worth efforts in this area of simple, first step preprocessing at the collection source.

2. There is a need for an analysis capability, operating on line, in real time, at the output of the ECM equipment. Such a system would selectively sort and measure signal parameters of interest. Output would be data in semi-reduced form acceptable to machines for further processing. The result could be saving of time and computer capacity at the central processing-interpretation node. The effect of this pre-processing is bandwidth compression of the collected information and an increase in the signal-to-noise ratio, all representing a significant economy in higher level computer processing time and volume handling demands. The signal environment is becoming and will continue to become increasingly complex and sophisticated. These facts underline the need, early in the reconnaissance cycle, for an advanced analytical capability and pre-selection of recorded data including elimination of redundant and/or irrelevant signals.

Research-Studies

Advanced pattern recognition techniques would be a requisite. Other requirements are scan devices and a miniaturized computer for automatic measurement of signal parameters such as pulse width, repetition rate, antenna scan rate and signal intensities. Rapid aperture scan of imagery might be the basis for accept-reject procedures as well as transforming the data into a machine acceptable output.

New functional devices of molecular electronics may well play an important future role in this area. Semi-conductor laser beam scanning possibilities and electro-optical advances are possibilities.(Rivkin S. M. 1964)

3. Need for wideband or alternative mode for transmission of imagery in limited war situations. This would be in keeping with the concept of immediate extraction and access to critical information in fast moving tactical situations. Under normal surveillance conditions, such a transmission capability would eliminate data volume pile-ups and result practically in real time, on line, processing possibilities.

Research-Studies

Research areas would be communication theory and information theory. Studies would be needed in the areas of bandwidth/time trading, transmission rates for given bandwidths and resolution factors. Video transmission is an accomplished fact. Application to direct handling of both image and nonimage forming data on a real time basis and in a reasonably secure mode of transmission will require intensive research. It is directly related to the unmanned satellite problem of reconnaissance. Discussion in any detail in an unclassified report is decidedly limited.

B. There is a Growing Need to Improve Handling Rates and Capacities in the Areas of Photo Processing and Photo Interpretation.

In-flight processing methods would significantly improve the time element. In the relatively near future techniques may be radically changed and processing simplified thus permitting in-flight handling. The possibility of the production of a transparent positive would eliminate negative reading errors, improve the time element and increase accuracy.

Automatic pre-processing techniques are needed to eliminate distorted, unreadable or nonessential photographic data. There is also a need to eliminateor de-emphasize those portions which are of no value.

Electronic image intensification techniques may play a significant part in eliminating unwieldy processing methods; in the storage of imagery; and in the possibilities of using machine aids in the photo interpretation process.

Research-Studies

Research could profitably be spent on new methods of photographic processing and the elimination of the troublesome chemical methods. Electronic image intensification techniques should be investigated and research in this promising area encouraged. Computer storage and handling of imagery is an interesting area and may be further stimulated by electronic intensification techniques. Advanced pattern recognition techniques would be required in any machine aids in photo interpretation. Search and sort techniques might also involve pattern recognition, perhaps of the relatively simple template comparison methods.

Note that materials research and molecular electronic research areas have applications in many of the problem areas discussed. The new phenomena and new functional devices will have broad applications. The semi-conductor laser and electro-optical techniques may play a future role in photo area problems.

C. Need for Cross Correlation of Sensor Data Across A Wide Spectral Range.

This is the multi-sensor concept of confirmation of intelligence. Sensors operating in different portions of the spectrum "see" different characteristics of the same target or target area. The intelligence picture which results from their correlation is the result of the "addition" of these various target characteristics. The result is (1) increased total intelligence (2) a "confirmed" intelligence. The new intelligence is multi-dimensional with dimension equal to the number of different spectral ranges correlated to form it. Such intelligence could be given specific probability weightings along a continuum of intelligence accuracy. It is possible that these correlations could be at least initiated at the time of collection (in an airborne surveillance environment for example).

Research-Studies

Research would involve analysis of the semantic content of imagery-Methods of image/language transformation-Analysis of differentials and commonalities in images of the same target from sensors in various parts of the spectrum. (Photographic-Radar-Infrared-SLAR-etc.). Methods of selection and merging of the complementary characteristics to form an integrated, multi-dimensional unit of intelligence would be developed. Methods would be developed for evaluating and quantizing this multi-sensor "confirmed" type of intelligence whose dimensions would be equal to the number of forms of sensor images integrated to produce the unit product. It is probable that in the flight phase of reconnaissance, only basic, first steps can be taken in sensor cross-correlation techniques with the remaining work performed at the processing point.Interest is in the correlation and integration of the particular characteristics of the intelligence stemming from each type of sensor involved and not in simple correlation in time, location, and platform attitude.

D. Need for Analog/Digital/Hybrid Techniques and Systems in Intelligence Processing

There is a high probability that an imperative need will become established for hybrid analog/digital processing in the coming decade. Applications might include (1) advanced, automatic ECM analysis capability; (2) cross-correlation of spectrum wide sensor data; (3) machine acceptable ECM outputs; (4) wide band transmission of imagery; and (5) centralized automatic monitoring and control functions including integrated ship systems. Problems involve digital readouts of analog data from imagery, photos, maps, equipment dials, scope faces, signal pattern grids, etc. The capability will be a critical requirement in machine storage of imagery and graphical information and in any machine aid to photo interpretation problems. At the present time data volume at various processing locations comes close to saturating the capability. An increased flow might well result in overwhelming demands and degraded operation. Many repetitive operations are manual using various aids such as limited spectral range analyzers, various types of filters, etc. Analog-digital-hybrid techniques and mechanisms are needed for real time, on-line processing of such material as photo, infrared, acoustic, radar, telephoto, ELINT, etc. Ideally research should be pursued with the final goal of evolving a new type of information processing system which will handle wide band, high information rate, analog and digital data. Special programming techniques would have to be developed for such a hybrid system.

Research-Studies

1. Optical techniques applicable to "read" problems involved in scan analysis of imagery, scope faces, dials, photos, etc.

2. Molecular electronics-Simple, efficient, light-generating devices and advanced fiber optics probably applicable. Research involves microelectronics, molecular electronics and materials research.

3. Research on the nature and characteristics of wide band (imagery), high information rate, analog and digital intelligence data. Relation of these characteristics to organization and design of an information handling system with a capability of operating in analog-digital and hybrid modes-on line, real time, under centralized program control.

Involved would be (1) mathematical techniques related to the calculation and handling of analog data parameters, (2) programming techniques suitable to analog, digital and hybrid processing operations, (3) problems of cross-correlation and merging of common intelligence from various sensors and sources. Research would probably be broken down into a half dozen sub-areas with the object of developing a new class of intelligence processing systems.

8.3 Intelligence and Information Processing--Needs-Research-Studies.

A. Direct Data Input to Computers.

There is a pressing need for the solution of the problem of coupling raw or unfinished intelligence sources directly to a computer. Time constraints and inefficiencies of peripheral computer equipment impose a heavy penalty on the handling of intelligence materials. Nano-second oper ation of internal computer operations contrast unfavorably with slow peripheral equipment speeds and with the time killing processes of tape preparation, card punching, etc. These procedures contribute heavily to the problem of overwhelming data volumes and general inefficiencies of overall system processing capabilities including data pile-ups, information flow lags and other aspects. Direct input capabilities are needed to eliminate the bottle neck of multiple duplication of incoming data on the forms presently required to get it into the machine.

Research-Studies

Information theory: Channel characteristics-Problems in imagery transmission-Bandwidth/time compressions-Coding theory-error coding.

Linguistics: Semantic content of imagery-Language structure, coding and format interrelationships-imagery/language transformations. Comparative analysis of information content of various types of sensors for same target (multisensor correlation).

Studies: Nature of machine input demands in terms of language, format, electrical characteristics. Nature of present intelligence traffic flow at a given processing center. Transformations required for machine acceptance (both image and non-image data). Outline of experimental test procedures and setups. Storage forms for imagery amenable to pictorial or textual form of retrieval.

B. Need for Cross Correlation of Image and Nonimage Forming Data.

This represents a further step in data cross correlation techniques as a means of integrating intelligence to achieve a "confirmed" intelligence of high accuracy and rating. Imagery (photo, radar, infrared, etc.) concerned with a target or a "situation" would be cross correlated with one, several or all other sources of information on the same target or situation (printed, hand written, acoustical information, etc.) The merging of the complementary characteristics of the various sources forms an intelligence product of high reliability which could be quantitatively rated as multi-dimensional intelligence along an intelligence continuum.

Research-Studies

Research in specialized areas of linguistics would be involved. The important concept of semantics of imagery would be a central effort. Following this would be problems of image/language transformations.

A basic study area would be the nature and characteristics of imagery, contrasts and commonalities with textually created images. The research area of digitalized, topological descriptions of imagery will be of importance.

C. Need for Associative Retrieval of Intelligence.

At both tactical and strategic levels of intelligence handling, there is critical need for "associative retrieval" of information. Such a capability is of importance to all aspects of information handling including technical information, intelligence abstracts, photographic, pictorial and other imagery relating to intelligence. In the advanced, developing forms of associative retrieval, the elimination of hierarchic structures characteristic of the traditional methods of information retrieval will result in significant flexibilities leading to a broader, integrated, "gestalt" viewing of the stored intelligence and its total pattern groups. The capability also radically reduces the probability of the dangerous situation, common in retrieval systems of any stature, of intelligence items lying fallow; unidentified or lost in the mazes of complex recall terminologies or indexing structures.

It is conceivable that at decentralized processing areas, at the level of the individual analyst, the basic principles of associative retrieval could be incorporated into simple manual or semi-manual systems. This would be of interest to the "Poor Boy" concepts of minimum, function/cost relationships.

The developing forms of associative retrieval or recall will have application in many areas including that of learning machines and areas of so-called "artificial intelligence." Research efforts and trends indicate considerable military interest in immediately practical and near future applications of associative retrieval to areas involving machine aids to decision. (Computer C&C Co. 1964)

Research-Studies

Research areas involved will include classification theory; association matrices; principles of semantic mapping; problems of enumeration (categories); invariants (commonalities); representative assemblies (associated item groups). (Hayes R. M. 1963).

D. Need for Advanced Methods in Quantification of Intelligence Items or Intelligence Products Resulting From Correlated Data.

Effective quantification is an important concept in stratifying intelligence. The result would be a more unified product, responses to which would be less subjective and more logically ordered. Application of the concept would probably be most useful at strategic levels and in the developing flow of operational intelligence at fleet intelligence centers and other sources. Application at tactical levels could have its dangers and the approach would have to be studied in great detail. At this level (a CVA carrier for example) application might be restricted to the intelligence products which evolve in the data base as a result of periods of surveillance, multi-sensor data, and items received from higher level sources. The first need is the advanced development of quantifying methods. The second is incorporation of the methods into machine aids to decision making. These two problems represent extremely important research areas for the coming two decades.

Research-Studies

Probability Theory: Probablistic "tagging" of information. Bayesian aspects-Factor analysis-Intelligence threshold raising.

Multi-dimensional Intelligence: Development of methods for quantification of multi-dimensional intelligence resulting from cross correlation of sensor data on the same target from a number of sensors across a wide range of the sensing spectrum. . . . or resulting from cross correlation of data from image and nonimage forming intelligence materials. In this report, non-image material refers to written, recorded, or to textual materials which might refer to common or related intelligence items.

E. Advanced Methods of Intelligence Processing at the Level of the Individual Analyst or Small Groups of Analysts.

With increasing volume and density of intelligence information flow there may be need in the near future for specialized information storage and retrieval capabilities. Advanced manual methods might prove effective and applicable but considerations should include ranges of processing methods from manual and semi-automatic through small computer processing using hand or desk size units. Advanced methods would involve associative storage and retrieval techniques, summarizing capabilities, automatic abstracting, updating and pruning methods. The rapidly advancing field of microelectronics has already produced and will continue to produce miniaturized, hand and desk sized information processing machines with continually increasing capacities and capabilities. With such equipment the relationship between the machine and the user becomes an intimate one; the continually growing simplicity of use and intercommunication may establish ideal conditions for intelligence use of such aids.

Research-Studies

Contributing research areas would include classification theory, advance methods of indexing, principles of associative retrieval, abstracting techniques, and the semantic aspects of language economy.

A study should be made of the particular needs of the individual analysts. The increasing volume and density of intelligence flow indicates a real need for the application of advanced principles in the organization of knowledge.

A feasibility study should be made of the application of such advanced methods to the particular needs derived from the study above. The advanced methods might be incorporated into purely manual information handling methods or into simple semi-automatic systems.

A contributing research area is materials research and micro-electronic techniques and the availability of desk and hand-held sizes of computers with large capacity memories.

F. Need for Common Command and Control Language, For Common Intelligence Terminologies, Common Intelligence File Structure and Special Vocabularies.

There are critical areas of language needs in both intelligence and command and control systems. In intelligence systems the need is for standardization of intelligence terminology with particular emphasis on the nomenclature for reference to various specific types of intelligence. It is vitally important for geographically separated intelligence processing areas to use the same terminology in handling and referring to the same type of intelligence item. By "handling" is meant any of the intelligence processing steps including collection, analysis, interpretation, storage, retrieval (associative retrieval), display, dissemination, etc. The continuing development of multiple access computers will or may make this need paramount. Another critical area is the need for a common structure (world wide) for intelligence files.

In command and control areas there is an important and recognized need for a common C& C language. In the particular area of military messages the need is for economy of expression and terminology. A study involving the vocabulary characteristics and formats of military messages would be extremely useful in a number of areas including machine translation (NATO, and Soviet/bloc languages), abstraction, routing, switching, storage, retrieval, selective filtering, etc. Another problem area is that of specialized vocabularies of high economy. An example might be a naval air arm vocabulary.

In general the language problem area is an important one. Much of the research being done in the area of machine translation will be useful and applicable to these problems. A common C&C language, standard intelligence terminologies and special vocabularies would be significantly reflected in all types and levels of data exchange operations; (1) in the design of data display devices; (2) in associative retrieval techniques; (3) in indexing and storage techniques; (4) in data dissemination techniques; (5) in economies of both time and data flow volumes; (6) in effecting significant economies in transmission time, machine processing time and reaction time.

Research-Studies

This is almost purely a language area research problem involving language structures with respect to economy and semantic clarity (elimination of ambiguities). Comparative linguistics, syntactics and semantic studies being done in the area of machine translation could directly contribute to the problems.

Studies should be made of intelligence terminologies and other special vocabulary areas (air arm for ex.). The goal again is language economy, clarity, and standardization of usages. The problem areas of economy, clarity and selection of standards would directly involve critical consideration of future capabilities of direct computer inputs (elimination of card punching, tape preparations, etc.).

G. Need at Strategic Levels for Advanced Automated Capabilities in Processing, Storage, and Retrieval of Large Volumes of Multi-Source Intelligence Materials.

At top strategic levels of intelligence handling there is need for an advanced, multi-level, modular, storage, retrieval and information handling capability which would incorporate the following:

1. Large volume handling of documents, journals, texts, articles, etc.

2. Handling of intelligence items, reports, messages, imagery, photos, maps, sketches and full day report texts.

3. Machine abstracting and summarizing capabilities.

4. Controlled, selective, multiple access capabilities to selected levels, security keyed within specific constraints.

5. Single item retrieval or multi-level, variable depth associative retrieval capabilities, across selected system levels, based on content addressable memory, parallel access and automatic internal structure loading.

6. Rapid parallel access capability under threat. Access would be to a selected critical level of the system for rapid parallel, simultaneous, retrieval and transmission of that level's memory store or its summarization to another location.

7. In general information storage and retrieval problems at strategic levels would profit by significant advances in the following critical areas:

   a. Efficient communication between machines and between men and machines. This is a function of the effectiveness of the system organization and the classification techniques used in the internal storage structures.

   b. Techniques and mechanisms for storage and retrieval of imagery or pictorial intelligence such as sketches, graphs, maps, charts, photographic materials, etc.

   c. Improved methods for the effective control of large files which may be distributed among several geographically separated computers. A common, well defined intelligence terminology is an important factor here.

      Effective techniques in the operation and control of a single file which might be accessed by several independent computers.

   d. Reduction of the language barrier between the user and the machine. One immediately practical approach to this critical problem area is research to develop improved methods of querying the system for specific items of information or for areas (associated groups of items) of information. Involved would be machine assistance in framing, analyzing and refining such queries. A related problem is the "depth" or multi-level concept in retrieval which requires internal storage structuring amenable to associative retrieval at levels representing degrees of detail. (Overall Summary-Abstracts-or Complete detail)

Research-Studies

Research covers about every area of linguistics. Classification theory, advanced indexing, syntactical and semantic aspects of abstracting, associative memory, storage and retrieval techniques.

Other research areas would include, advanced character and pattern recognition, aperture-grid analysis of imagery, studies in the semantic content of images, storage methods for image transformations, new man/machine intercommunication patterns, query-answer modes of intelligence retrieval, machine translation capabilities and controlled multiple access operational modes. Current references of interest to advanced processing areas include the following: Fano M. 1964; Computer C & C Co. 1964; Anatole L. 1963; Selfridge O. 1964. (See bibliography addendum.)

8.4 Need for Rapid, Accurate, Machine Translation of Foreign Language Materials

Many sources of intelligence information provide data in foreign languages. This problem is being compounded today by the increasing number of foreign operational areas of interest. The perfection of an electronic language translating system is a high priority need. Research in this area is of critical interest. Presently operating systems provide rough, useful, translations but at present are unwieldy.

Not only is mass translation of large volumes of information needed (documents, reports, journals, newspapers and other forms), but it may also be necessary to disseminate intelligence in languages other than

English. It is of interest to note that language research in general has direct application in a wide range of fields including natural language access to computers and resulting reduction of the man/machine programming barrier; common command and control language problems; information storage and retrieval problems; the problem of the role of language in human problem solving; special vocabulary problems such as common intelligence file terminologies, advanced computer programming methods such as the heuristically slanted list processing techniques and so on. It is an area of research of extremely broad scope and one which promises to pay high dividends in the solution of intelligence and military system problems.

Research Areas

Research areas of importance are comparative morphological language studies, syntactical studies, semantic studies, and the development of dictionary and glossary material from foreign texts in various disciplines. Research in semantics is widely felt to be critical to further progress in machine translation as well as in other areas. It is the least penetrated and may be the key to the solution of many diverse problems in heuristics, problem solving and in artificial intelligence. The section in this report on machine translation (6.0) discusses M. T. research further.

8.5 The Poor Boy Concept

"Poor Boy" represents a stabilizing concept in system design and operation. In terms of conventional data processing it is at the opposite end of the spectrum from system thinking which results in vast computer complexes and overautomation. It is in effect a countermeasure against this broad tendency in intelligence and information processing systems. The Poor Boy concept recognizes that at specific system levels there is a critical functional need for advanced, automated systems of high complexity. On the other hand, there are areas and levels which can be served efficiently by simple, economical systems, in many cases manual systems. An example of this manifested itself during the observations made by HRB-Singer personnel in the 1963 Naval exercises. A need was indicated in some areas for simple, flexible, means of rapid information retrieval which might operate on the level of a simple data file, but make use of advanced techniques in indexing, classification, parallel access and associative retrieval. Similar systems would conceivably be useful at the intelligence analyst level. Other applications might include the need in special areas for rapid, simple, reference retrieval of some of the less well-known and perhaps complex aspects of Naval operational doctrine and philosophies.

As a result of the glamour of machine technologies, there is a (strong) tendency to consider automation a panacea, obscuring the distinction in the real functional needs of these levels. Many times the result is system imbalances in terms of over-automation, cost/function ratios, operational flexibility and efficiency. The final result may well be a major computer system operating at one third its capacity, doing work which could effectively be done by (1) a smaller computer, (2) by simple office machine techniques, (3) by semi-automatic methods, or (4) by well-organized, advanced methods of manual operation.

The tendency to over-automate may be related to overcentralization of processing facilities. Overcentralization has the further disadvantage of increased vulnerability in terms of destruction, damage, or serious mal-functioning. Decentralization of processing, where processing or prepro-cessing steps are effected at the collection site or data source, has the advantage of acting as a source filter which can eliminate useless, redundant, or false data and thus contribute to an exponential reduction of the continually increasing volumes of data flow. In many cases preprocessing performed at lower system levels requires relatively simple means, may be routine in nature and has the general characteristics of wide band filtering.

Research-Studies

In general the Poor Boy concepts of efficient system performance within the framework of stabilizing cost considerations should be further clari-fied and given more concrete form against the background of a system structure study. This is more fully discussed in the following section.

A study should be made of the feasibility of improving system effi-ciency by the incorporation of advanced information processing concepts into manual or semi-automatic processes and/or systems. Examples of such concepts are classification theory, specialized indexing techniques, storage or file structures amenable to associative retrieval methods, advanced abstracting techniques, etc. These areas are presently contributing to advanced machine techniques. Application of the principles involved to relatively simple systems is considered to be a promising area of development.

8.6 System Structure Study

A system structure study should be made in order to profile key points and system interfaces which should be monitored as critically important indicators of system efficiency and performance. Such a structure study would also be the tool by which the "Poor Boy" concepts described above would be achieved.

Interface problems in complex military systems at times operate to seriously degrade system operation. It is often impossible to determine (1) that a particular inefficiency or malfunctioning exists, (2) at what particular node or interface it is operative, and (3) its nature, characteristics and accumulative effects on system operation.

In a structure study, it would be possible to develop a specific diagnostic methodology which would permit location, analysis and solution to such nodal or interface problems. A first study should be "macroscopic" in nature and examine the systems environmental interfaces. Following this, a "microscopic" approach would be the longer term effort. It would analyze the system's internal nodes, flows, transformations, flow and control impedances, processing patterns, machine languages etc. Utility measures of total system effectiveness should be developed as a result of such a structural study.

9.0 REPORT SUMMARY

The correlation of research trends and technological advances with present and future system problems and needs is a continuously evolving task of broad scope. This summary, on the basis of state of the art and research trends considered in the report, points out research areas of direct and critical importance to intelligence, information processing and command and control systems. The focus of the report is on a two decade time span.

The chart of Figure 7 summarizes important research areas whose broadness of scope and status is such that their future developments will apply not to single, specialized, problems, but to the solution of wide ranges of present and future system problems and needs. The chart is of course a generalization. The body of the report should be consulted for an expansion of its implications.

This is an era overwhelmed by fantastic volumes of information, by continually increasing information processing demands, by problems of man/machine intercommunication and interrelationships and by numerical and nonnumerical problems whose complexity and myriad variables cannot be handled by the most powerful of modern computers. It is the era of the "information sciences." As such it is understandable that the critically important research areas in which activities and efforts are world wide (NBS 1963) fall into the categories of (1) epistemology or the systemization and probing of the bounds of knowledge and (2) instrumentation or automata, which refers to the tools, technologies, devices and systems through which we may solve future problems and realize necessary goals.

As the chart of Figure 7 indicates, epistemology subdivides into research areas involving studies in (1) language and language structures and meaning in terms of morphology, descriptive linguistics, syntactics and semantics; (2) modern heuristics and General System Theory which are new approaches to the solution of numerical and nonnumerical problems whose form and complexity overwhelm deductive and purely analytical methods. These two, new, related approaches appeal to induction, controlled inference, methods of analogy and the study of laws and principles common to "systems" of all types including electronic, biological (Bionics), mechanical, economic and sociological;

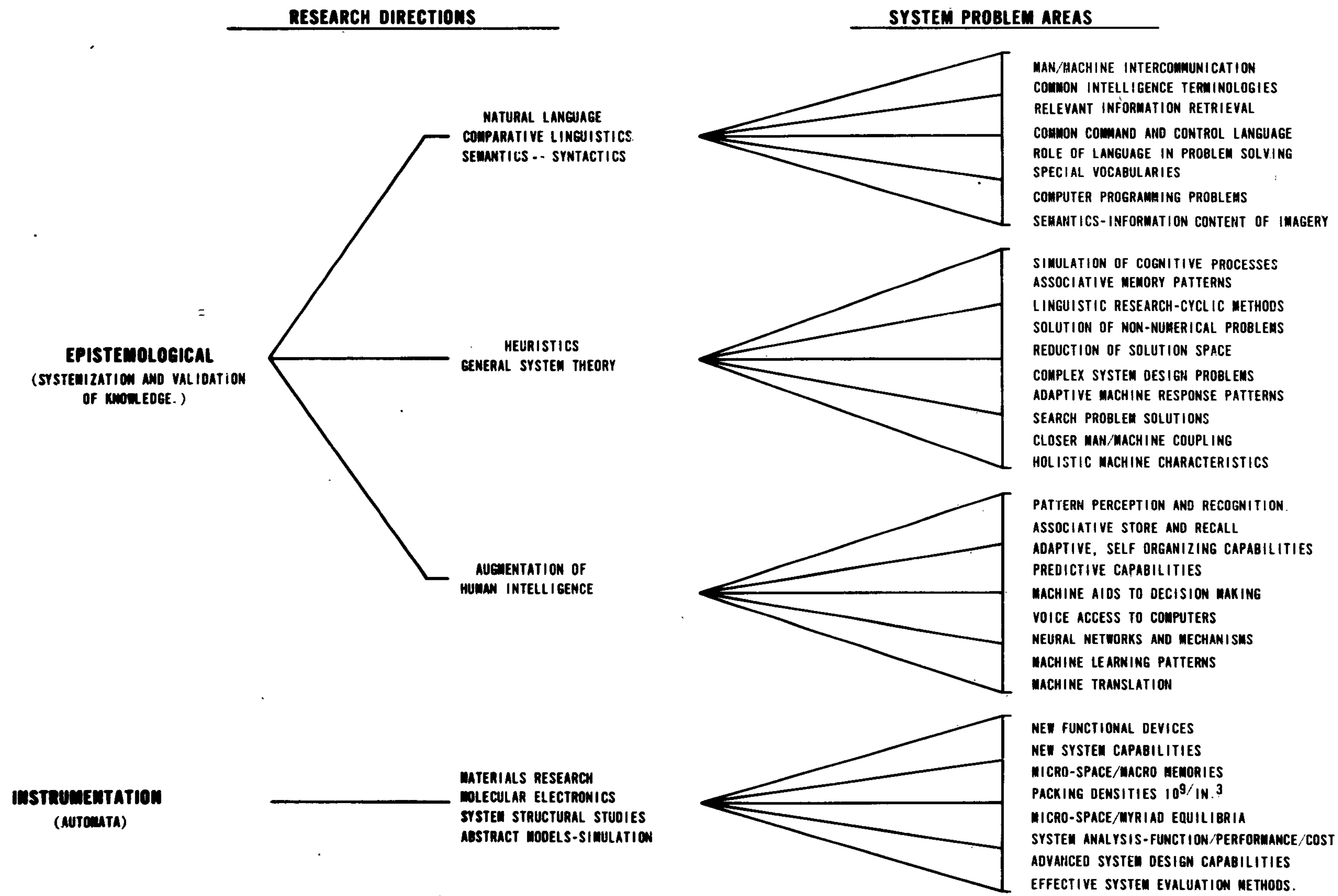

FIG. 7 - RESEARCH AREAS OF SIGNIFICANCE TO INFORMATION SYSTEM PROBLEMS

(3) the augmentation of human intelligence which is concerned with improving man's own capabilities and with the development of advanced machines capable of aiding man and extending his intellectual powers. Such machines would be capable of solving complex problems and of aiding man in critical decision areas where at fantastic machine speeds, vast volumes of data can be filtered, processed, associatively organized, summarized and presented to man for critical choice of alternatives and final decision making. This is the area in which the human, with experience, background, intuitive and judgemental capabilities excels all machines. It is the area in which he must be freed from overwhelming detail and routine.

The other category of important research areas having critical implications for future advanced systems falls under the heading of "instrumentation." Included are materials research, molecular electronics, abstract modeling, simulation and system structural studies. All are concerned with complex problems in terms of advanced system design, applications of new physical phenomena, new functional devices, new system capabilities and with effective methods of system evaluation.

It is difficult to summarize a report of this nature. The following list very briefly indicates some of the areas covered.

1. The rise of "systems" as an integrating factor in research. (report section 1.0)

2. The need of system design areas to take a bolder approach in the use of advanced methods, including modern heuristics, General System Theory and the concepts of environmentally adaptive, self organizing systems. (report sections 2.0, 3.0)

3. Adaptive, self-organizing systems - U.S. and Soviet attitudes on machine or artificial intelligence. (3.0)

4. The future impact on military and information systems of new phenomena and new functional devices coming out of materials research, microelectronics and molecular electronics. (4.0, 5.0)

5. Need, at strategic and intelligence processing levels, for advanced capabilities in machine translation. U.S. and Soviet research activities in M. T. (6.0)

6. Advanced concepts in nonconventional computers - The trend from von Neuman calculators to the "inductive" machine. The future potential of optical techniques in information processing. Conventional computers and new techniques. (7.0)
7. Some advanced system problems and applicable research and study areas. (8.0)

Figure 7, previously discussed, has shown important, broad, categories of research areas which reflect the demands of the present era on military systems. As an extension of this, Figure 8 correlates a set of specific, future system problems and needs, with related research areas, potentially capable of providing solutions in the coming two decades. Figure 8 also complements and expands the details of the discussion of information, intelligence and command control system problems in Sections 8.0 (page 51) through section 8.6 of this report.

The circles in the two dimensional matrix of Figure 8 simply relate system needs with related research areas. Reading down the vertical columns (research areas) gives an indication of the number of system problems to which a particular research area may contribute. As an example, the research area of column 1 involving adaptive, self organizing systems could possibly contribute to nine specific system needs, beginning with "increased coverage of enemy activity" and ending with "advanced system design." Reading across the rows of the matrix identifies research areas which might be involved in the solution of the particular system problem or need.

Note that attention can be focused on any one circle, relating a single system problem with one particular research area. By analysis and detailed listing of all system and operational characteristics of the problem, and by an analysis and depiction of all avenues and aspects of the particular research area pertinent to the problem characteristics, a third dimension for the matrix can be generated. This information, in the form of a summarizing study, could serve as a basis for detailed organization of research planning and studies.

As the present report is in the nature of a relatively broad survey, limitations in depth of treatment have been imposed. Future efforts in monitoring and evaluating research and technological developments and potentialities might be based upon an amplification of selected areas shown in this report to be of critical interest to intelligence and military systems. Technical literature and symposium sources of information could well be further enriched by personal interviews with scientists of stature, working in the specific fields of interest.

FUTURE SYSTEM NEEDS / RELATED RESEARCH AREAS	ADAPTIVE, SELF ORGANIZING SYST COGNITIVE PROCESSES GENERAL SYSTEM THEORY	MATERIALS RESEARCH NEW PHYSICAL PHENOMENA NEW FUNCTIONAL DEVICES.	RESEARCH IN MACHINE TRANSLATION LANGUAGE MODEL DEVELOPMENT ALGORITHMS-SEMANTIC THEORY.	MODERN HEURISTICS HUMAN PROBLEM SOLVING PATTERNS NEW PROGRAMMING TECHNIQUES	PATTERN RECOGNITION TECHNIQUES. PERCEPTRON CONCEPTS NEURAL NETS-SIMULATION TECH	LANGUAGE RESEARCH SYNTACTICS-SEMANTICS LANGUAGE UNIVERSALS COMPARATIVE LINGUISTICS.	DECISION THEORY BAYESIAN INFORMATION PROCESSING FACTOR ANALYSIS-INTELL. TAGGING.	ADVANCED OPTICAL TECHNIQUES IN INFORMATION PROCESSING AND DISPLAY	SEMANTICS OF IMAGERY IMAGERY TRANSFORMATIONS. NEW FORMS OF IMAGERY STORAGE.	CLASSIFICATION THEORY. SET THEORY. ABSTRACTING-INDEXING-SEMANTIC MAPPING	NEW CLASSES OF INFORMATION. PROCESSING MACHINES. NEW INTERNAL STRUCTURES. INDUCTIVE MACHINE CAPABILITIES.	MICRO AND MOLECULAR ELECTRONICS MICRO SPACE-MACRO MEMORIES. MYRIAD RANDOM ELEMENT CONCEPTS.	SPEECH ANALYSIS AND SYNTHESIS NATURAL LANGUAGE AND VOICE ACCESS TO COMPUTERS	ANALOG-DITAL-HYBRID TECHNIQUES IN INFORMATION PROCESSING
1 INCREASED COVERAGE OF ENEMY ACTIVITIES	O	O	O		O			O				O		O
2. PRE-PROCESSING TECHNIQUES TO REDUCE INFORMATION PROCESSING LOADS	O	O			O			O	O			O		O
3. ON-LINE ECM ANALYSIS CAPABILITY	O	O			O		O	O	O		O	O		O
4. NEW, ADVANCED, PHOTO PROCESSING-PHOTO INTERPRETATION TECHNIQUES		O			O			O	O		O			O
5 CROSS CORRELATION OF WIDE SPECTRAL RANGES OF MULTI-SENSOR DATA		O			O			O	O		O			O
6. ADVANCED, WIDE BAND, SECURE TRANSMISSION OF IMAGERY					O			O	O			O		O
7. DIRECT COMPUTER INPUTS OF RAW INTELLIGENCE	O	O	O		O			O	O	O	O		O	O
8. ASSOCIATIVE RETRIEVAL OF INTELLIGENCE	O		O	O	O	O		O		O	O			O
9. QUANTIFICATION OF INTELLIGENCE.				O	O	O	O			O				
10. ADVANCED METHODS OF INTELLIGENCE PROCESSING AT ANALYST LEVEL.				O	O		O			O		O	O	
11. COMMON C & C LANGUAGE - COMMON INTELLIGENCE FILE STRUCTURES - SPECIAL VOCABULARIES			O	O		O	O			O				
12. ADVANCED, AUTOMATED, PROCESSING - STORAGE - RETRIEVAL CAPABILITIES AT STRATEGIC LEVELS.			O			O	O	O		O	O	O	O	O
13. IMPROVED MAN/MACHINE COMMUNICATION AND INTERRELATIONSHIPS.	O			O	O	O		O	O		O		O	
14. RAPID, ACCURATE, MACHINE TRANSLATION OF FOREIGN LANGUAGES.	O		O	O	O	O		O			O		O	
15. INCREASED SYSTEM INVULNERABILITY	O	O			O							O		
16. ADVANCED SYSTEM DESIGN.	O	O		O	O		O	O	O		O	O	O	O

FIG 8 - RELATED RESEARCH AREAS IN TERMS OF FUTURE SYSTEM PROBLEMS

10.0 Report Bibliography and Descriptor Arranged References

The report Bibliography following this section, represents information sources for the material in this report. Following the Bibliography is a group of selected references in areas thought to be of special interest. These groups are arranged under the descriptor headings of: (1) Augmentation of Human Intelligence-Artificial Intelligence; (2) General System Theory; (3) Modern Heuristics.

It should be noted here that valuable information on activities and efforts in many of the areas of research discussed in this report is to be found in the publications of the National Science Foundation. Of specific interest are the volumes entitled "Current Research and Development in Scientific Documentation." They are published by the Office of Information Service of the National Science Foundation in Washington, D. C. Although not directly quoted in this report, these surveys have supplied a background on world-wide research in a range extending from processing equipment through artificial intelligence.

Note-For the few references which may not be found in the report bibliography, see the bibliographic addendum which follows the bibliography.

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1. Artificial Intelligence-Augmentation of Human Intelligence
2. General System Theory
3. Modern Heuristics

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